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THE REFRACTION OF THE EYE

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THE REFRACTION OF THE EYE

INCLUDING A COMPLETE

TREATISE ON OPHTHALMOMETRY

A CLINICAL TEXT-BOOK FOR STUDENTS AND PRACTITIONERS

BY

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WITH ONE HUNDRED AND NINETEEN ENGRAVINGS

NINETY-SEVEN OF WHICH ARE ORIGINAL

New York

THE MACMILLAN COMPANY

LONDON: MACMILLAN & CO., LTD.

1900

Norwood Press
J. S. Cushing & Co. — Berwick & Smith
Norwood Mass. U.S.A.

TO

My Father

H. C. DAVIS, M.D.

AND

My Twin Brother

GEORGE E. DAVIS, M.D.

THIS VOLUME

IS AFFECTIONATELY DEDICATED

PREFACE

Since the introduction of the perfected ophthalmometer into ophthalmic practice, rapid strides forward in the art of the refraction of the eye have been made. With its aid, the practice of fitting glasses quickly and accurately and, as a rule, without the aid of any mydriatic whatever has been attained. It is to the end of demonstrating the clinical and practical use of the ophthalmometer, and of recording the advances made in the science and practice of the Refraction of the Eye, that this book has been written. Some half dozen books on Ophthalmoscopy and Retinoscopy have been written, and the time is opportune for one on Ophthalmometry. We have one such book in French, Javal's *Mémoires d'Ophtalmométrie*, but none in English.

While the present book is intended more especially for beginners, and for those who have not had the advantage of personal instruction in the use of the ophthalmometer, it is hoped that its clinical details will interest those in active practice, and who are well versed in the use of the instrument of which it treats. I am especially desirous that it shall be read by a certain rather considerable number of oculists who have the ophthalmometer in their offices, but who, from the want of a proper understanding of it, through faulty instruction or a lack of personal instruction, do not use it: or, if they do know how to use it, do not take into consideration the limitations of the instrument, and abandon it on that account. Through the citation of a great number of clinical cases, together with numerous diagrams illustrating them, I have

tried to show the virtues of the ophthalmometer, while I have not omitted to note its limitations. In that way, I have hoped to present the instrument in the true light and to justify the claims made for it.

In composing the book, I have departed from the beaten path, and have devoted the greater part of it to the report in detail of clinical cases illustrating practical points in the use of the ophthalmometer. In other words, instead of a theoretical and didactical discourse, I place a sufficient number of cases themselves (one hundred and fifty in all) before the eye of the reader, which are reported in full, so as to be easily understood. To be more explicit still, I may say I have made my teaching correspond, so far as it is possible in a book, to the instruction that we give at the Post-Graduate Medical School, where the instruction is entirely clinical.

I have given an *Index of Cases* at the close of the book, so that the reader who has a case that he does not fully understand, may turn to this index and look for cases in it similar to his, and then refer to the full report in the body of the book. By comparison he may get a solution of the case that is puzzling him. I have done this in order that the student may not be "lost with a case," as is too often true when he refers to the larger text-books wherein no such index is given. It has been my experience that more can be taught the student by one concrete case illustrating a point in question, than by many pages of abstract deduction concerning cases which have never been presented to the student himself.

After giving a brief description of the instrument and the rules for its use, with some general considerations, I have treated successively, in separate chapters, of its practical use in cases of Simple Hypermetropia and Hypermetropic Astigmatism, Compound Hypermetropic Astigmatism, Simple Myopia and Myopic Astigmatism, Compound Myopic Astigmatism, and Mixed Astigmatism, giving many cases and using diagrams to show the

point of focus of the principal meridians, so that the merest tyro must understand them. Incidentally throughout the book, I have endeavored to show the utter uselessness of a mydriatic in fitting glasses in the vast majority of cases, even in young subjects. If the Ophthalmometer is correctly used and a good routine method followed in putting the glasses in the trial frames in the subjective test, as here suggested and fully explained, the use of a mydriatic is, with rare exceptions, never necessary in order to give the right glasses.

I desire to express my sincere thanks to Professor St. John Roosa for his kindness in looking over the manuscript, and for many valuable suggestions both as to the matter and the form of the composition.

Mr. Fred Stuart has given me much assistance in proof-reading, which I here acknowledge with thanks.

Mr. Norman P. Findley has made the original drawings for the book. For the cuts of instruments I am indebted to Mr. E. B. Meyrowitz and the publishers of the book.

A. EDWARD DAVIS.

NEW YORK, December, 1899.

CONTENTS

CHAPTER VI

CHAPTER VII

CHAPTER VIII

CHAPTER IX

CHAPTER X

CHAPTER XI

APPENDIX

THE REFRACTION OF THE EYE

CHAPTER I

HISTORY OF THE OPHTHALMOMETER — DESCRIPTION OF THE INSTRUMENT

History of the ophthalmometer. — The ophthalmometer is an instrument designed to measure the radius of curvature of the cornea in its various meridians. By its use the presence or absence of corneal astigmatism is ascertained; if present, it gives the amount and the axis of the astigmatism.

The instrument was invented by Helmholtz who, as early as 1854, published a description of it together with his conclusions as to the exact form of the cornea, as measured by the instrument.[1] Although very accurate in its measurements, the instrument, as constructed by Helmholtz, was not a practical one. In order to use it the patient was placed six feet in front of it, and from fifteen to twenty readings made; then, before the astigmatism was ascertained, mathematical calculations had to be made. As such, it was used in the laboratories of only a few men and for strictly scientific purposes.

It was not until 1880, when Javal and Schiötz made alterations and improvements in the instrument, that it became practical for office use, and it was not until 1889 that they perfected the instrument into its present model. As now constructed, it has about reached the limit of improvement, except as to minor details; consequently the purchaser is safe in buying it and with the assurance that it will not soon be a back number.

Dr. Swan M. Burnett, of Washington, was the first Ameri-

[1] "Ueber die Accommodation des Auges," *Archiv für Ophthalmol.*, 1854.

can to use the Javal ophthalmometer. As early as 1885 he published a paper in the *Archives of Ophthalmology*, Vol. XIV,

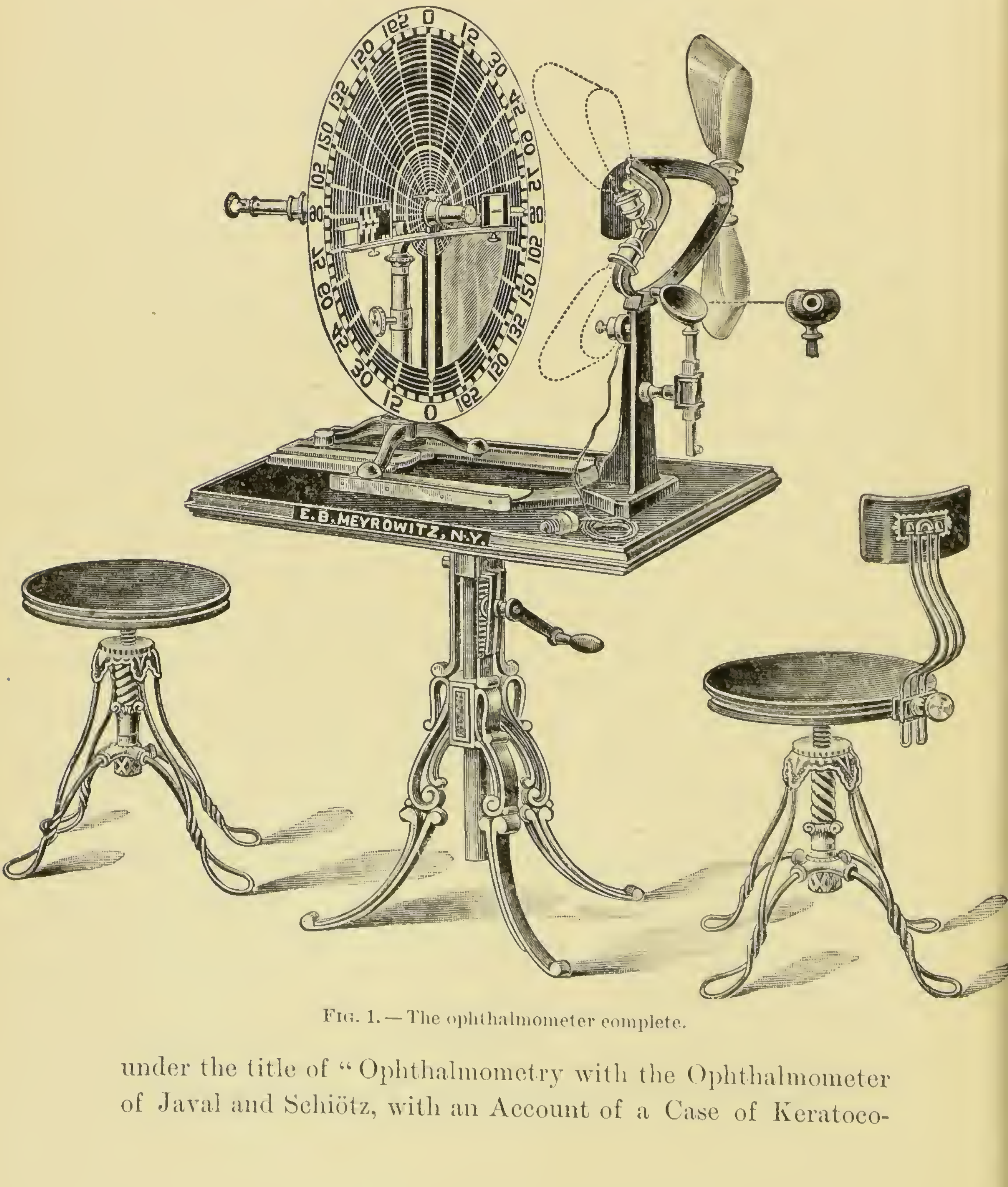


Fig. 1. — The ophthalmometer complete.

under the title of "Ophthalmometry with the Ophthalmometer of Javal and Schiötz, with an Account of a Case of Keratoco-

nus." Dr. Henry D. Noyes, of New York, began using the instrument about the same time. Both of these instruments were old models. In 1887, Dr. Burnett gave a description of the old model instrument in his *Treatise on Astigmatism;* and in the same year, 1887, in the *Reference Hand Book of the Medical Sciences*, Dr. John Green, of St. Louis, gave a description of the instrument with a cut. The instrument remained comparatively unknown, however, in this country until 1889.

When the new or "1889 model" came out it found among its advocates, among others, Dr. D. B. St. John Roosa, of New York, who by his earnest and persistent advocacy of the instrument, especially in the class-room and in the hospital, where practical demonstrations of its use and value were given, did much to bring it into general favor. Other writers in America who have helped to bring the ophthalmometer into esteem are: Speakman, Koller, Ring, Weiland, Van Fleet, Wurdeman, Swasey, Woodward, Valk, De Schweinitz, Norris, myself, and others.

Construction of the instrument. — To be able to use the ophthalmometer well the oculist should at least be somewhat familiar with its construction.

The instrument is composed of the following parts: —

1. A *telescope* on an upright, supported by a tripod.

2. A *graduated arc*, which is the quarter of a circle and attached to the telescope at right angles to it.

3. Two *mires* or reflectors which are attached to the graduated arc.

4. A large steel *disk* (Placido's) attached to the telescope, just back of the graduated arc.

5. The *planchette* or base for the instrument to rest on.

The telescope. — The telescope is made of brass and has a fixed length. It contains: (*a*) an ocular or eye-piece (0, Fig. 2, *A*) of .7 inch focus or 56 diopter power; (*b*) double objectives (*L* and *L'*, Fig. 2, *A*) of 11.2 inch focus each, or about 4 diopter

power; (*c*) a cross-thread to show when the eye-piece and objectives are in adjustment; (*d*) and a double refracting Wallaston prism (*W*, Fig. 2, *A*).

(*a*) The eye-piece can be made to approach or to recede from the objectives by means of a small pin which is fixed on the side of the brass ring that holds the eye-piece, sliding in an oblique groove in the side of the telescope. When the cross-threads in the barrel of the telescope are brought into view by this means, it shows that the eye-piece is in proper focus with the

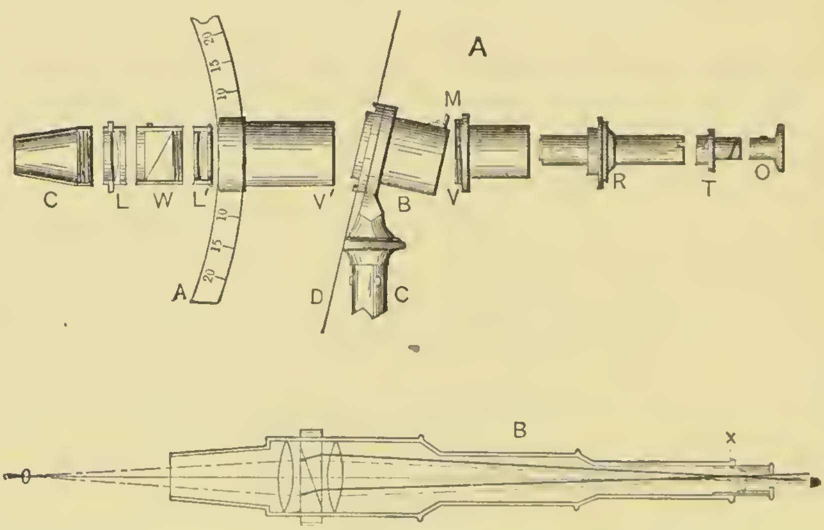


FIG. 2. — *A*, showing vertical sections of the telescope and its component parts. *B*, horizontal section of the telescope.

proximal objective (*L′*, Fig. 2, *A*); and when the distal objective (*L*, Fig. 2 *A*,) is brought into exact focus with the eye observed, a perfect image of the mires is possible. If the observer is myopic, he has to push the eye-piece inward or to the right to get the cross-threads in focus; if he is hypermetropic, the eye-piece has to be pulled outward or to the left to properly focus them. The eye-piece should always be properly adjusted for the cross-threads before focussing the instrument on the observed eye. The imported instruments, made by Goubeaux, of Paris, have graduations along the oblique slit in which the pin on the eye-piece slides. These graduations are so placed that

each corresponds to a displacement of the eye-piece to the extent of 1 mm.; each millimeter of displacement corresponding to a change in the observer's eye of 3 diopters. For example, when the pin on the eye-piece stands at zero an emmetropic observer should see the cross-threads in the telescope plainly, while a myope of 3 diopters would have to turn the pin one graduation to the right, and a hypermetrope of 3 diopters would have to turn the pin one graduation to the left in order to see the cross-threads distinctly.

(*b*) The two objectives are exactly alike. Each has a diameter of 40 mm., or 1.6 inches, and a focal distance of 280 mm., or 11.2 inches. They are the most perfect lenses made, being both achromatic and aplanatic.

They are so placed in the barrel of the telescope that the crown of one is turned toward the observed eye, and the crown of the other toward the observer. By this means the flints of the two objectives are kept opposed and next to the bi-refracting prism.

(*c*) The cross-threads are two very fine wires stretched at right angles to each other across the barrel of the telescope about 1 inch in front of the eye-piece and about 11.2 inches behind the first objective, L'. They are there simply to show when the eye-piece is in proper focus with the objectives.

(*d*) *The bi-refracting prism* (Wallaston) placed between the two objectives is in fact two prisms, placed apex to base and base to apex. In this country, at least in the instruments manufactured by Meyrowitz and Georgen, these prisms are made from the best mountain crystal quartz. They possess the power of doubling objects, that is, are bi-refractive, if ground in a certain direction with regard to the axis of the quartz. The amount of the deviation or doubling produced by each prism depends on the angle at which it is ground.

One of the prisms is ground diagonally with the grain of the quartz (*a*, Fig. 3), while the other is ground at right angles

to it (a', Fig. 3); see cut, looking down on them from above as they are placed in the telescope of the instrument. Thus placed, their axes are at right angles to each other and at the same time transverse to the axis of the telescope. Each prism when ground at a certain angle causes a definite amount of deviation; and by using two prisms, apex to base and base to apex, the deviation takes place from each side, thus getting twofold the deviation that would be caused by one prism and at the same time keeping the doubled images nearer the center of the field. Furthermore, these prisms are placed in the telescope with their plane of doubling in exact line with the plane of the graduated arc, which latter is fixed to the telescope of the instrument at right angles to it by two screws in a brass collar.

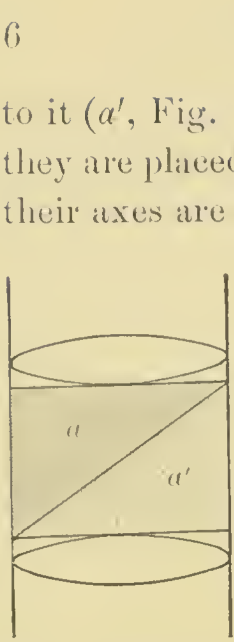


FIG. 3.—The bi-refractive prism as placed in the telescope.

It is very important, therefore, that these two screws should not be meddled with; for, if moved in the least, the arc and the plane of the prism is altered, and the instrument cannot be used again until readjusted by an expert.

The prisms in Javal's instrument produce a deviation of 2.95 mm. when the instrument is focussed on an object at double the focal distance of the objective, or 460 mm. When, therefore, the instrument is properly focussed on the cornea, the latter is doubled by the prism, and each point of the image reflected from the cornea is displaced to the extent of 2.95 mm. Consequently, if the image of the object reflected from the cornea happened to be just 2.95 mm. in length, the deviation of 2.95 mm. caused by the prism would allow the edges of the doubled image to just touch, as in Fig. 4.

Say the image of the arrow 1–2 is just 2.95 mm. in length, and by the deviation caused by the prism each of its points are displaced correspondingly the distance of 2.95 mm.; then the

tail of the secondary image, 1′–2′, will just touch the head of the primary image, 1–2.

In this way we are enabled to measure the size of the corneal image by the amount of displacement it is necessary to

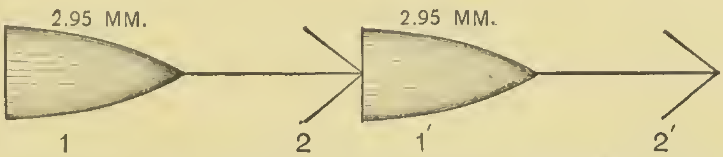


Fig. 4. — Showing the extent of displacement in the Javal-Schiötz instrument.

give to each point of the image in order to have the edges of the doubled images just touch.

Instead of an arrow, Javal takes for his object the distance between the inner edges of two *mires* or reflectors, 1 and 2, Fig. 7. Here, as in the case of the arrow, the prism, from its fixed position in the telescope, causes a deviation of 2.95 mm. Consequently, if the two mires are so arranged on the arc of the instrument that, by this deviation of 2.95 mm., the inner edges of the images of the two mires are just touching, it is quite plain that the diameter of this image must be just 2.95 mm. Furthermore, it is equally plain that the distance between the inner edges of the two mires, in this instance, is equal to the size of the object, in fact, is the object which gives a reflected image 2.95 mm. in diameter.

The bi-refracting prism in the Javal-Schiötz instrument causes a fixed deviation of 2.95 mm.,[1] the arc on which the mires move has graduations to show the distance apart of the two mires, and thereby the size of the object; and twice the focal distance of the objective determines the distance of the object from the cornea. With these three points known it is easy to find the fourth, the radius of curvature of the cornea

[1] An extra tube with a prism causing less deviation and therefore a smaller image is furnished with the instrument which is of use in cases of marked variation from the average radius of curvature of the cornea.

in its various meridians, and thereby ascertain the presence or absence of astigmatism — the object of the ophthalmometer.

The *graduated arc* is an arc with a radius of its inner edge of 290 mm. When focussed on the observed eye it is concentric with the cornea. The posterior edge of the arc is graduated into equal spaces and numbered, the numbering beginning at the center and extending in each direction to 40 spaces. Each one of the divisions on the posterior edge of the arc, taken in connection with the doubling of the image by the prism, stands for a diopter mark. For example, if, with an eye under observation and the arc in the horizontal meridian, the images of the mires just touch when the mires on each side of the arc stand at the 20 mark, it shows that the refractive power of the horizontal meridian of the cornea is 40 diopters. If now we turn the arc to the vertical meridian of the cornea and the images of the mires overlap, say three steps, it shows 3 diopters of astigmatism, which may be verified by the graduations on the posterior edge of the arc in the following way. While still looking at the images through the telescope as they appear overlapped there, move the graduated mire outward along the arc till the images are left just touching again. Then by looking at the posterior edge of the arc we will find that the graduated mire has moved the distance of just three graduations; thus verifying the amount of astigmatism present and at the same time showing the vertical meridian of the cornea to have a refractive power of 43 diopters.

On the right side of the arc on its inner edge are some fine graduations and some figures. On the instrument with the single movable mire these figures go from 6 mm. to 10 mm.; on the instruments with double movable mires (improved) from 5 mm. to 13 mm. By noting the position of the graduated mire on the right side of the arc in relation to these graduations when the images of the two reflectors just touch, in any meridian whatever, the number corresponding

indicates the radius of curvature of the cornea in that particular meridian in millimeters. These figures are very important, therefore, and should be noted carefully, for by them we are able to register the radius of curvature of the cornea in millimeters in its various meridians.

Two *mires* or *reflectors* are attached to the arc. One of them is a parallelogram, 60 mm. long by 30 mm. wide, and, in the unimproved instrument, is fixed at 20 on the left-hand side of the arc. The other is a graduated mire, each graduation or step is 10 mm. long by 5 mm. broad, and counts as 1 diopter. There are eight of these steps.

Dividing the mires into halves are two narrow black lines, called guide-lines. The lines are parallel with the planes of the arc. They serve to show when the arc is in one of the chief meridians of curvature of the cornea, that is, when it is in the meridian of longest radius of curvature, or in the meridian of the shortest radius of curvature. They do this by showing perfectly straight and opposite each other when the arc is turned to either of the chief meridians of curvature (see Fig. 5), but run obliquely toward each other in all other meridians (see Fig. 6). Of course where there is no corneal astigmatism, the cornea being uniformly and evenly curved, they will remain straight and opposite each other in all meridians. As we have to find one of the chief meridians of the cornea, that is, get the "primary position" or starting point in measuring corneal astigmatism, these lines are of much importance. A small pointer or indicator is attached to the outer side of each mire, which points to figures on the periphery of a large disk, where the axis of the meridian is marked in degrees of a circle. These short indicators on the reflectors serve as a check to a long indicator which is attached to the middle of the graduated arc and at right angles to it.

FIG. 5.

FIG. 6.

This long indicator shows the direction the arc is in when the long black lines dividing the reflectors become straight with each other. For example, say the black lines dividing the mires become straight when the arc is in the horizontal meridian of a cornea having astigmatism with the rule. The long indicator, since it is at right angles to the arc, will be pointing directly downward (directly upward, however, as seen in the telescope, because the image is an inverted one) to 0°, which is the same as regards axis as 180°, for 180° just completes the half of a circle.

It will be noticed that 0° or 180° is marked on the big disk directly above and directly below, and does not occupy the horizontal meridian, as is usually the case. This is due to the fact that the long indicator is at right angles to the arc whose direction it indicates. Therefore, when the arc is really in the horizontal meridian (0° or 180°) the long indicator is in the vertical meridian, consequently the 0° has to be put there. This explains why 0° is marked in the vertical meridian and 90° in the horizontal meridian on the disk.

When the long indicator points to 0° the short indicator should point exactly to 90°; in this way the latter serves as a check to the long indicator, as above stated.

The *disk* (Placido's) is a large circular sheet of steel 640 mm. (25.6 inches) in diameter attached to the telescope at right angles to it and just back of the graduated arc. Upon this disk are concentric white circles on a black background, also radiating lines extending from its center. The concentric white circles are five degrees apart, numbering from the center to the periphery a distance of 45°. They are constructed on the law of tangents, that is, the radius of each circle represents the tangent of an arc drawn from the center of the graduated arc.

The circles marked 15° and 30° are broader than the others, and on the 30° circle beginning above, the radiating lines from

the center of the disk are numbered in the degrees of a circle from 0° to 360° — a complete circle (see Fig. 1). By numbering both the concentric circles and the radiating lines in this manner, this disk can be used as a perimeter; for the same reason it can be used to make observations on the cornea outside of the visual line.

At the periphery of the disk, between the 40° and the 45° circles, is a large white border. On this white border are large inverted figures 15° apart. Instead of numbering from 0° to 360°, as did the small figures on the 30° circle, they stop at 180°, then begin again and number up to 180° or 0°, where they first began (see Fig. 1). These figures appear upright or straight when viewed as a reflected image from the cornea, for this image is inverted.

On the right side of the disk in the horizontal meridian the numbers 3 mm., 4 mm., and 5 mm. appear. These are meant to aid in measuring the diameter of the pupil. In order to do so, however, an extra strong objective has to be put in the telescope, and an extra brilliant illumination obtained. If the pupil seems to extend out to the circle marked 3 mm., it is 3 mm. wide, etc.

On the opposite side of the disk are seen the figures 35, 40, 45, and 50. When viewed in the corneal image, if any one of these circles so numbered become tangent to itself (through the doubling caused by the prism), the figures denote the power of refraction, or dioptric power, of the cornea in that meridian. For example, say the circle marked 40 becomes tangent to itself — thus 00 — in the horizontal meridian; the refractive power of the cornea in that meridian would be 40 diopters.

The reason that the numbering at the periphery of the disk begins at 0° and goes to 180°, then repeats itself from 0° to 180° again instead of completing the circle of 360° (as in the 30° circle in small figures), is that both ends of any corneal meridian under measurement may be indicated by the same

number on each side of the disk. For this reason each mire has a short pointer on it. These pointers not only point to the same number of degrees on each side of the disk, but serve as a check at the same time on the long pointer or indicator. For example, when the short pointers each point to 0°, the long pointer should be exactly at 90°, at right angles. Again, by means of these short pointers and the double numbers on the disk, the angles of the chief meridians can be seen at once from the reflected image. This is one strong reason why this big disk should not be removed from the instrument and replaced by a smaller black velvet disk and upright numbering on a small medal disk facing the observer, as is now sometimes done by some Americans.

For a description of the improvements made on the Javal-Schiötz instrument and modifications of it, and for descriptions of other ophthalmometers, see Appendix.

CHAPTER II

PRINCIPLE OF THE APPLICATION OF THE OPHTHALMOMETER IN MEASURING ASTIGMATISM — RULES FOR ITS USE — ASTIGMATISM "WITH THE RULE" — ASTIGMATISM "AGAINST THE RULE" — WHY THE MIRES OVERLAP IN ASTIGMATISM WITH THE RULE AND SEPARATE IN ASTIGMATISM AGAINST THE RULE — WHY WE DEDUCT HALF A DIOPTER FROM THE READING OF THE INSTRUMENT IN ASTIGMATISM WITH THE RULE, AND ADD A HALF DIOPTER TO THE READING WHEN IT IS AGAINST THE RULE — RULE OF PROCEDURE WHEN THE MAIN MERIDIANS ARE AT 45° AND 135° — PRINCIPLE OF THE APPLICATION OF THE OPHTHALMOMETER

THE principle on which the ophthalmometer acts in measuring the radius of curvature of the cornea in its various meridians, and thereby marking the corneal astigmatism, *consists simply in the measurement of the size of a small image reflected on the cornea.*

In order to measure this image the more easily, it is first doubled by the bi-refracting prism in the telescope of the instrument. The objects furnishing this image are the inner edges of the two mires. The images of both the mires, as well as that of the disk, are doubled by the prism, so that, as viewed through the telescope, we have four mires and two disks (see Fig. 7). 1 and 1′ are the images of the graduated mire, and 2 and 2′ are the images of the rectangular mire. In practice, however, we pay no attention to the two outer images, 1 and 2,′ but notice simply the two inner images, 1′ and 2, in the oval space made by the overlapping of the double images of the disk (see Fig. 7). The distance, *a a′*, between the inner edges of the images of the rectangular mire, denoted

by the dotted line in Fig. 7, and $b\ b'$, the distance between the inner edges of the images of the graduated mire, each represents the amount of deviation caused by the prism, which is 2.95 mm. Now as $a\ a'$ is the image of the object under meas-

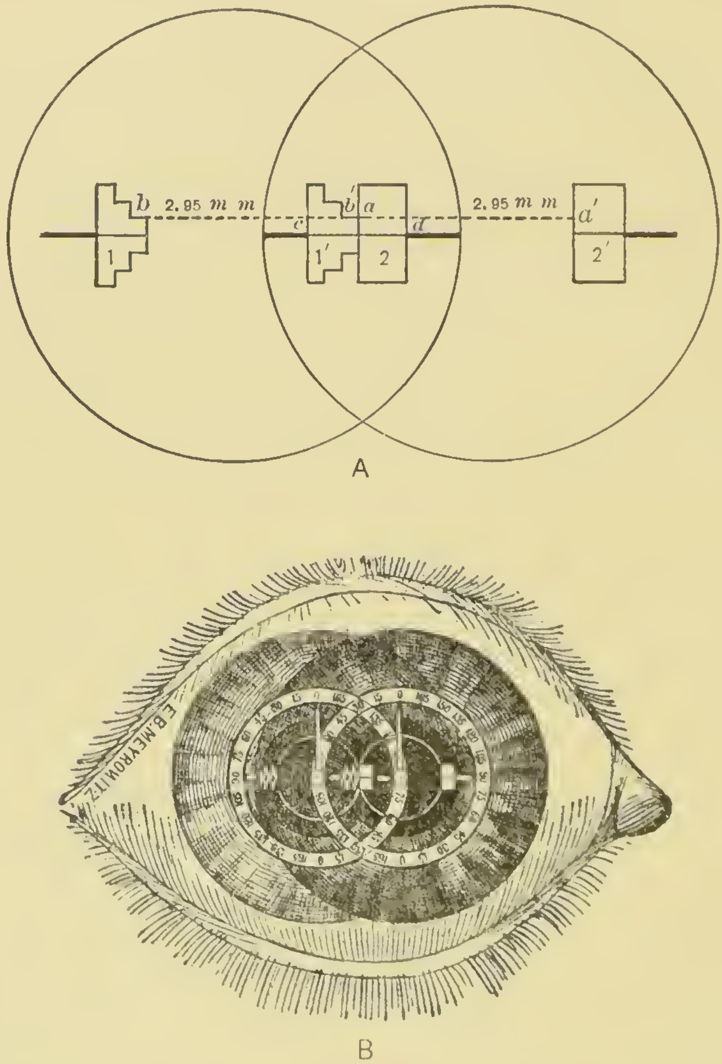


FIG. 7. — *A*, diagram of the mires alone. *B*, reflection of the whole instrument from the front of the cornea, with the arc at 180°.

urement, that is, the distance between the inner edges of the two mires, we know its size to be just 2.95 mm. in this instance. Take a case in actual practice. For example, when the instrument is focussed properly on an eye, the black lines dividing the mires become coincident with each other in the

horizontal meridian ($c\ d$, Fig. 7). This shows that one of the chief meridians of curvature of the cornea is the horizontal meridian. Approximate the images till they just touch, then turn the arc at right angles to the horizontal meridian. If there is no overlapping or separation of the images 1′ and 2, it shows that the vertical meridian of the cornea has the same radius of curvature as the horizontal. If the vertical meridian

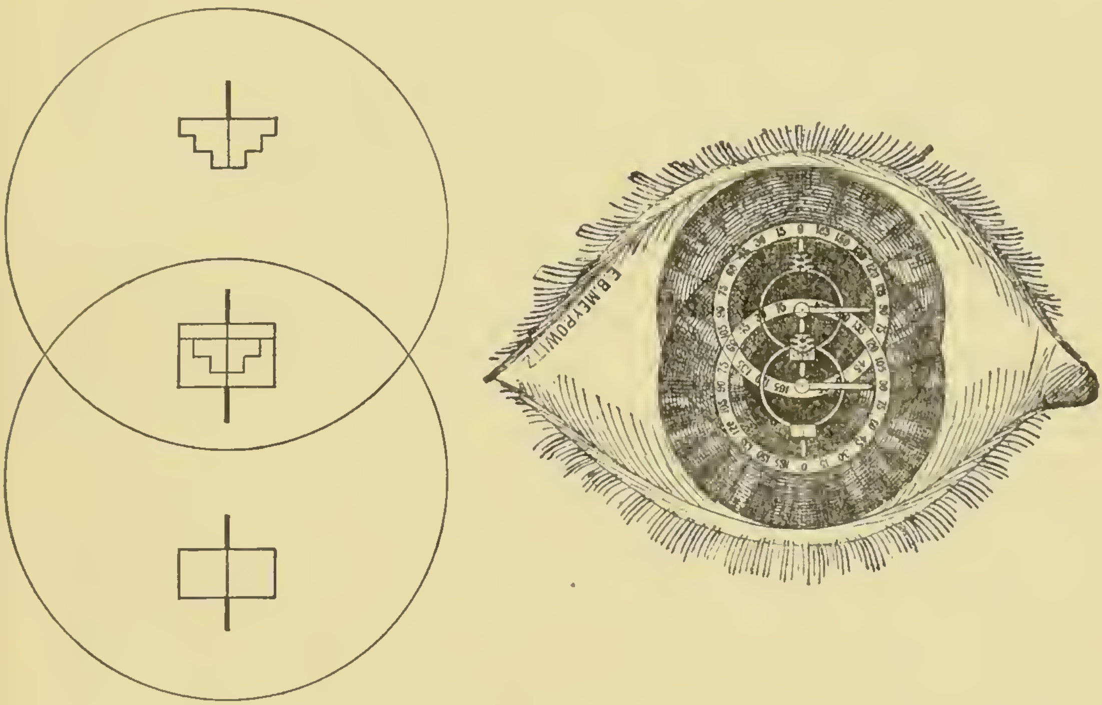


FIG. 8.—The same images as in Fig. 7, but with the arc at 90°.

has a shorter radius of curvature, the images will overlap to a certain extent, say, two steps (see Fig. 8).

This must necessarily be so, for the size of the object (the distance between the inner edges of the mires as placed on the arc) and the distance of this object from the cornea having remained the same, we must obtain a smaller image on a surface with a shorter radius of curvature. The distance between 1 and 1′ and 2 and 2′ remaining the same from the constant deviation caused by the prism, the reduction in the size of the

corneal image cannot take place in a change of length of these lines. It must be brought about, therefore, by an overlapping of the inner edges of the images 1′ and 2 (Fig. 8). The number of steps overlapped shows the amount of astigmatism, and the direction of the long and short indicators respectively shows the axis at which plus or minus glasses will be worn, in any case whatever.

RULES FOR ITS USE

These rules for the use of the ophthalmometer are taken in the main from articles on this subject by myself.[1] They are intended to be so simple, plain, and direct, that even the very beginner should be able to use the instrument by their guidance. Of course, personal instruction is always preferable to written, and, where it is possible, I would advise several lessons by some one skilled in the use of the instrument.

1. Have a perfect light. The light from a large north window; four 16-candle-power electric lamps; or two Welsbach gas burners with suitable reflectors, are all good illuminants.

2. See that the telescope, or tube, of the instrument is correctly adjusted, by sighting through it, and bring the cross-wires in good view. This is done by turning the ocular, or eye-piece, to the right when the observer is myopic, and to the left when he is hypermetropic. The further to the left that the eye-piece can be turned, and yet the cross-wires be maintained in good view, the better; and for the same reason which we follow in prescribing glasses — the weaker the minus and the stronger the plus glass the better, because by this means no extra accommodation is called into play.

3. Place the patient at the instrument with his chin on the chin-rest and his forehead against the forehead-rest, with his eyes wide open and upon a level. To know when the eyes are exactly horizontal, which is all important, sight through the

[1] *New York Medical Journal*, September 10, 1892, October 8, 1892.

transverse slit in the disk just above the tube, or telescope, of the instrument. This point cannot be insisted upon too much, for the least rotation of the head will throw the axis off 5° or 10° from what it really is, and then, when we come to the trial case, and the axes do not correspond, we are prone to blame the instrument when we are ourselves at fault.

4. The eyes level, we are now ready to place the blind in front of one eye and focus the other. To focus the eye, sight along the upper side of the tube through the notch (something like a gun sight) at the center of the cornea. Now sight through the tube, at the same time moving the instrument forward and backward on the planchette, and up and down by means of the screw, until the image of the disk, doubled by the prism in the telescope, and reflected from the cornea inverted, comes into view. Pay no attention to the two reflectors far out at the sides, but notice the two reflectors in the oval space made by the overlapping of the disks.

5. Obtain the "primary position." The "primary position" is nothing more or less than that point at which the transverse lines, dividing the reflectors into halves, become opposite, or coincident, and form one continuous straight line, which is an indication simply (when there is any astigmatism) that we have found one of the axes of the astigmatism. The other axis, in the great majority of cases, is 90° from this, therefore at right angles to it, and is the "secondary position." When there is no astigmatism, the transverse lines are always opposite and coincident. When there is irregular astigmatism, they are never coincident. To obtain the primary position, first turn the long indicator to 0°. If the transverse lines are coincident at this point, go no further; that is the primary position. If not coincident at the zero point, turn the tube from right to left — that is, the long indicator from 0° to 135°. If the transverse lines do not become coincident before or when 135° is reached, go no farther in that direction, but turn back to 0°,

turning this time from left to right, toward 45°; the lines will, necessarily, become coincident before 45° is reached. The primary position is never farther than 45° on either side of 0°. This I wish especially to emphasize, for if we turn farther than the 135° mark on one side or the 45° on the other, we will make the astigmatism "with the rule," when it is really "against the rule," and *vice versa.* When the lines become coincident at 135° or 45°, the extreme limits, being just halfway between 0° and 90° on either side, by preference take 135° as the primary position — this for the sake of nomenclature. We see then that the "primary position" may be at 0° or any point within 45° of that point, but never beyond. Having got the lines coincident, it is only necessary to approximate the reflectors to be ready for the next step.

6. That of obtaining the "second position." This is obtained by turning the long indicator 90° to the left from the primary position. If the reflectors overlap, there is astigmatism with the rule, and the number of steps of overlapping is the amount of the astigmatism. Say it overlaps two steps. It should be written thus: "Astigmatism with the rule, 2 D. 90° + or 180° – ." If the reflectors separate when the second position is reached, it indicates astigmatism against the rule. Before moving the indicator from the second position, approximate the reflectors again, and then turn back to the primary position, when the plates will overlap — say two steps, written thus: "Astigmatism against the rule, 2 D. 180° + or 90° – ." Following the rules above, the long indicator always points the axis the plus glass will be worn, and the short indicator on the reflectors the axis the minus glass will be worn — in any case. It may be asked why I prefer to turn the cylinder from right to left. Simply that I may have the sliding indicator below, where I can get at it through the holes in the disk below.

Of course the observer's eye should be properly corrected if he has any error of refraction.

Now, what does the instrument do? It gives the amount of the astigmatism and the axis. These points ascertained, the rest is easy.

As to the amount of the astigmatism as indicated by the ophthalmometer and that accepted by the patient, we need never be in doubt as to the proper glass to prescribe if we will only follow what Javal has taught us, that in astigmatism "with the rule" — that is, the vertical axis of the cornea being the more curved, let the astigmatism be hypermetropic, myopic, mixed, simple, or compound — we have only to subtract one-half to three-quarters of a diopter from that indicated by the instrument to have the proper glass; and in astigmatism "against the rule," the horizontal meridian of the cornea being the more curved, let the astigmatism be hypermetropic, myopic, mixed, simple, or compound, to give full correction we add half a diopter to that indicated by the instrument. The exceptions to this rule are rare, the variation of half a diopter too much with, and half a diopter too little against, the rule being a fairly constant one and one to be expected, in the great majority of cases. Of course the readings of the instrument should be verified by the ophthalmoscope and trial case before glasses are prescribed.

Astigmatism "with the rule." — There has been so much confusion in the minds of beginners, and I may say also even in the minds of men of considerable experience, about astigmatism "with the rule" and astigmatism "against the rule" that very explicit and short definitions of each will not be out of place here. Where the vertical meridian of the cornea, or any meridian in the neighborhood of the vertical meridian, that is, within 45° of the vertical, is *more curved* than the meridian at right angles to it, *that condition* is called *astigmatism with the rule.*

This is all there is to astigmatism with the rule; it simply means that the vertical meridian of the cornea, or one near it,

is more curved than the meridian at right angles to it. And since the vertical meridian, or one in the neighborhood of it, is, as a rule (perhaps in 75 to 80 per cent of all cases of astigmatism), more curved than the horizontal, or the meridian at right angles to it, the astigmatism in such cases is said to be according to the rule, or "with the rule." French writers often call this "direct" astigmatism, while they designate astigmatism against the rule as "indirect" astigmatism.

Many times beginners ask if hypermetropic astigmatism is not always with the rule, and if myopic astigmatism is not always against the rule. As a matter of fact, it makes no difference whether the astigmatism be hypermetropic (simple or compound), myopic (simple or compound), or even mixed, just so the vertical meridian of the cornea or one within 45° of it is more curved than the meridian at right angles to it, that is astigmatism with the rule.

In order that the reader cannot possibly go astray on this point, I will take an example of each form of astigmatism, and show by diagrams how it may be "with the rule" in every form.[1]

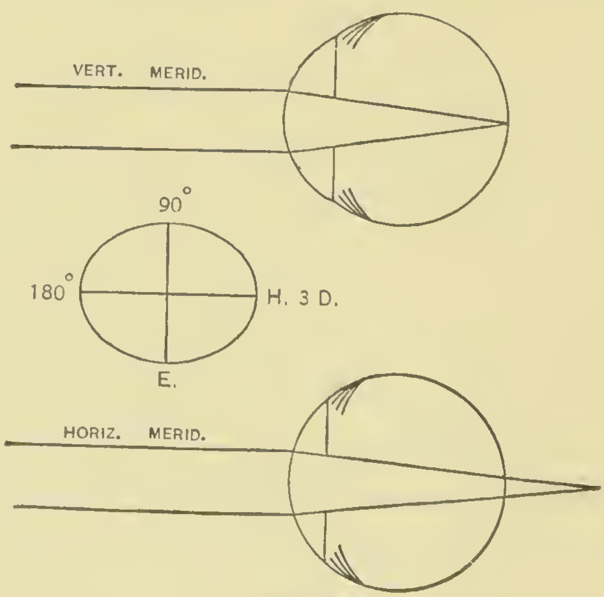


FIG. 9.

[1] Under the heading of astigmatism against the rule, I show how astigmatism may be "against the rule" in all its forms.

1. *Simple hypermetropic astigmatism with the rule.*—Figure No. 9 shows the vertical and horizontal sections of an eye with such an error of refraction. It is seen by this diagram that the vertical meridian is emmetropic and allows the rays of light to focus on the retina, and is more curved than the horizontal meridian which is flat and allows the rays of light to focus back of the retina. Therefore, according to our definition of astigmatism with the rule, this must be a case of it, for the vertical meridian is more curved than the horizontal.

2. *Compound hypermetropic astigmatism with the rule.*—In such a case the vertical meridian is flat and allows the rays of

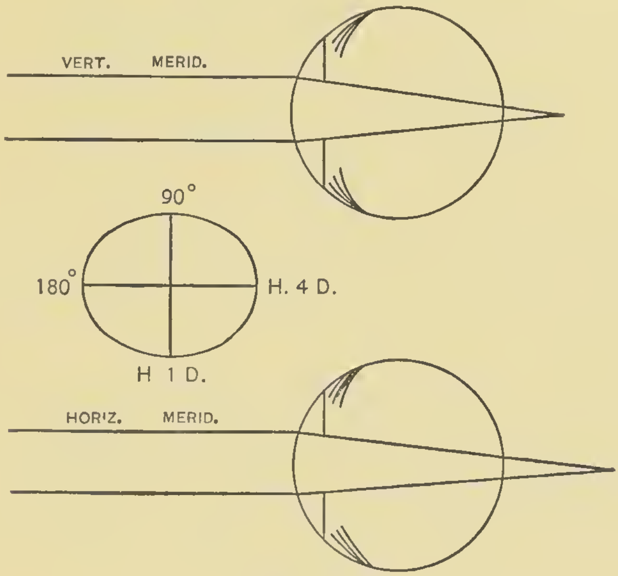


FIG. 10.

light to focus back of the retina, but it is not as flat as the horizontal meridian which allows the rays to focus still farther behind the retina. Here again the vertical meridian is more curved than the horizontal, and, of course, the astigmatism is with the rule, though it is compound hypermetropic.

3. *Simple myopic astigmatism with the rule.*—Here the vertical meridian is myopic, causing the rays of light to focus in front of the retina, and is more curved than the horizontal meridian which is emmetropic, and allows the rays to focus on

the retina. Now, this is with the rule, though it is myopic astigmatism — simply because the vertical meridian is the more curved.

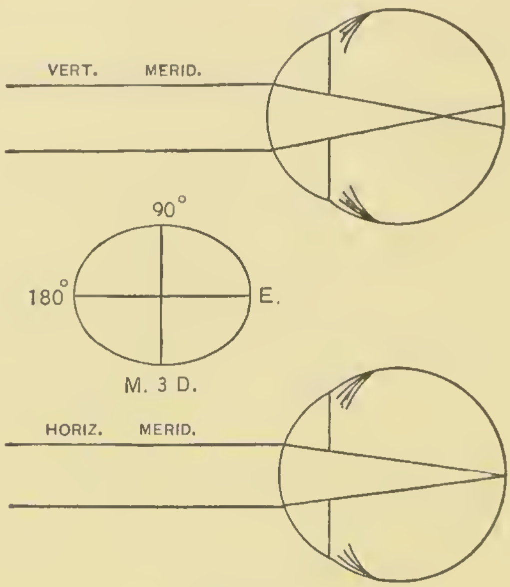


Fig. 11.

4. *Compound myopic astigmatism with the rule.* — The vertical meridian is more myopic and at the same time more curved

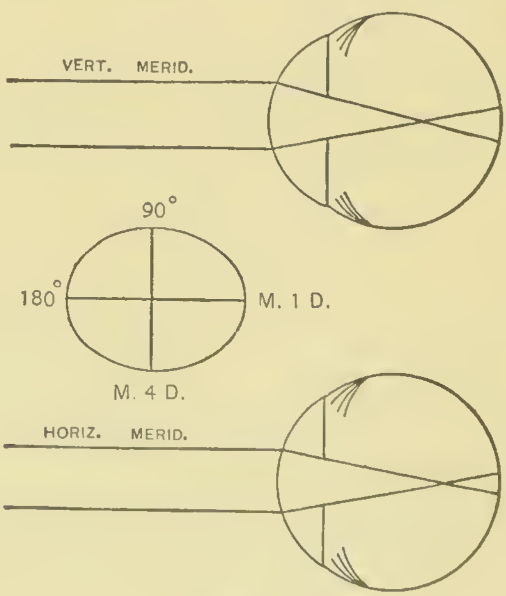


Fig. 12.

than the horizontal meridian, which latter fact makes it astigmatism with the rule.

5. *Mixed astigmatism with the rule.* — The vertical meridian is myopic and focusses rays of light in front of the retina, and is more curved than the horizontal meridian which is hypermetropic (flat, less curved), and focusses rays back of the retina. The astigmatism is with the rule, therefore, though mixed.

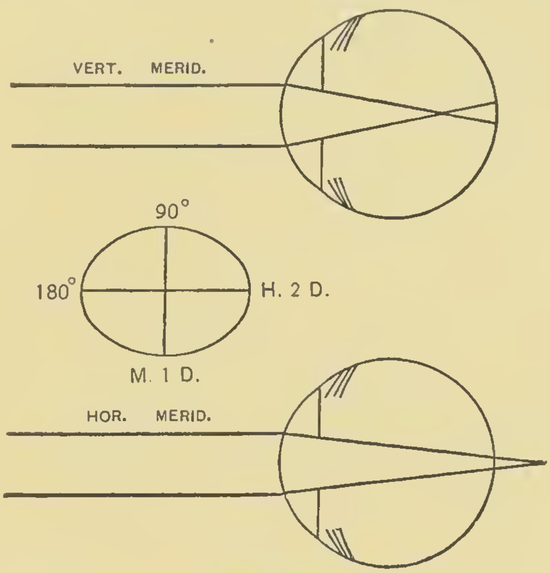


FIG. 13.

We see, then, by the above five diagrams that astigmatism may be with the rule in all of its forms; the only thing necessary to have it such, the *sine qua non*, so to speak, *is that the vertical meridian of the cornea or one in its neighborhood shall be more curved than the horizontal or the one at right angles to it.*

Where the vertical meridian of the cornea, or any meridian in the neighborhood of the vertical meridian, that is, within 45° of the vertical, is *less curved* than the meridian at right angles to it, that is *astigmatism against the rule.*

In other words, astigmatism against the rule means simply that the vertical meridian of the cornea is less curved than the horizontal; and this condition may obtain in any form of astigmatism — hypermetropic (simple or compound), myopic (simple or compound), and in mixed astigmatism, as the following diagrams show: —

1. *Simple hypermetropic astigmatism against the rule.*—The vertical meridian is hypermetropic, focusses rays of light back of the retina, and is less curved than the horizontal meridian, which is emmetropic, and focusses rays on the retina.

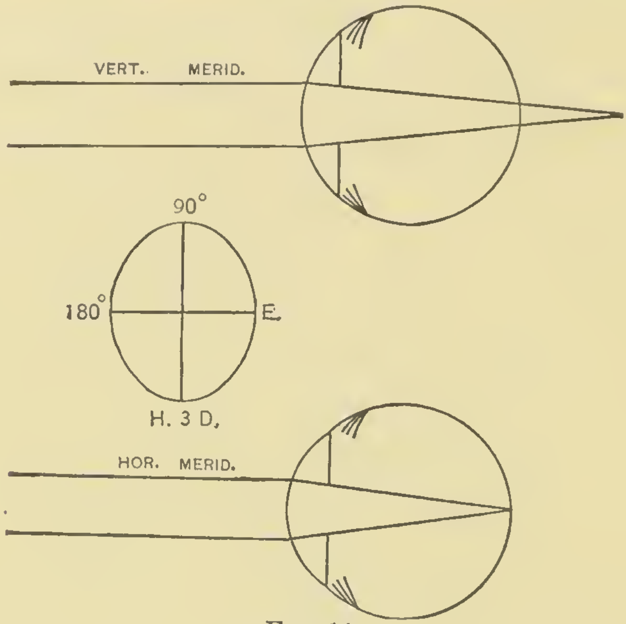


FIG. 14.

2. *Compound hypermetropic astigmatism against the rule.*—Here both meridians are hypermetropic, but the vertical more so than the horizontal, consequently the vertical meridian is

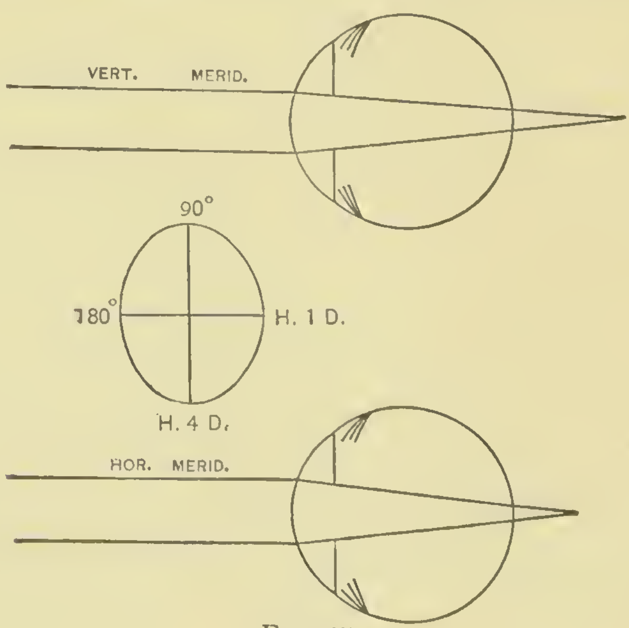


FIG. 15.

less curved than the horizontal. The astigmatism is, therefore, against the rule.

3. *Simple myopic astigmatism against the rule.* — The vertical meridian is emmetropic, focusses the rays on the retina,

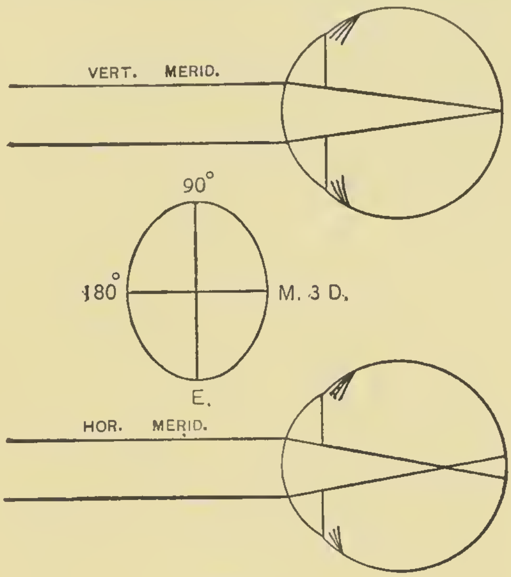


FIG. 16.

and is less curved than the horizontal meridian, which is myopic, and focusses rays in front of the retina.

4. *Compound myopic astigmatism against the rule.* — Here both meridians are myopic, but the vertical is less myopic than

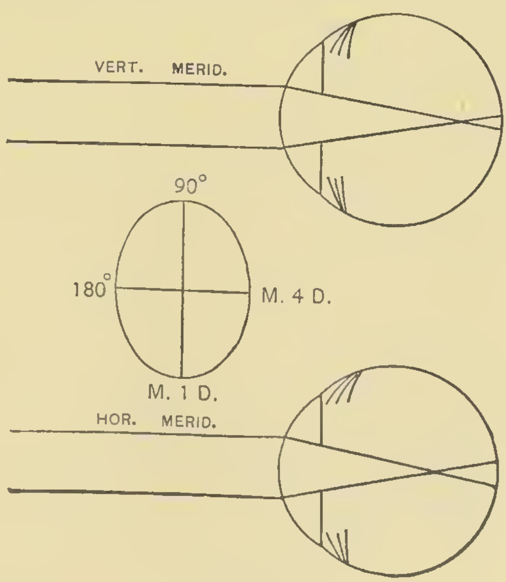


FIG. 17.

the horizontal, is less curved, and consequently it is astigmatism against the rule.

5. *Mixed astigmatism against the rule.* — The vertical meridian is hypermetropic, focusses rays back of the retina, and is less curved than the horizontal meridian, which is myopic, and focusses rays in front of the retina.

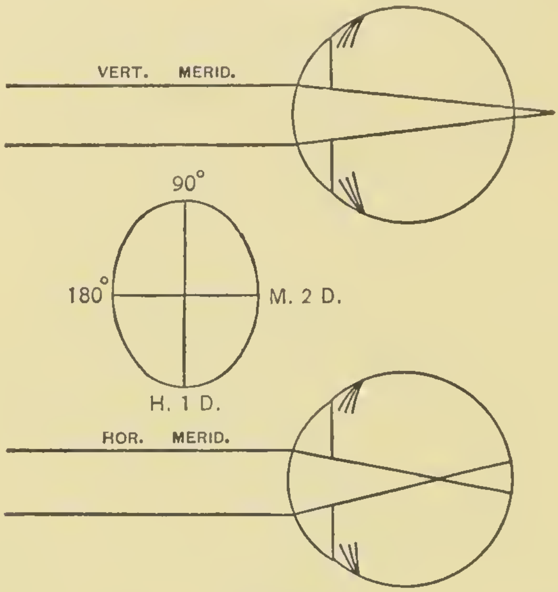


Fig. 18.

By the above diagrams we see that astigmatism may be against the rule in all its forms. *So long as the vertical meridian of the cornea is less curved than the horizontal, that is astigmatism against the rule.*

I have gone very particularly and minutely into this point of astigmatism with the rule and astigmatism against the rule, because I have found in my teaching at the Post-Graduate School of Medicine that it is a point on which most beginners are in doubt. I may add that I have seen many others who have used the instrument for a long time not clear on the question. Some authors are inclined to give but little importance to it, but I have found it of much value in instructing. Because, if, on finding the astigmatism with or against the rule with the ophthalmometer, you can teach the student to

picture in his "mind's eye," so to speak, the condition of curvature of the cornea and the position of the focal points of its two chief meridians of curvature in relation to the retina in the various forms of astigmatism, it greatly assists him in adjusting glasses. In fact, it makes him think of the eye under observation, and not of some abstruse rule in a text-book.

Why the mires overlap in astigmatism with the rule; why they separate in astigmatism against the rule. — It is a well-known fact to those who have used the ophthalmometer, that in astigmatism with the rule, the images of the mires overlap when turned from the primary to the secondary position; and that these same images in astigmatism against the rule separate when turned from the "primary" to the "secondary" position.[1] Why is this so?

Figure 19 shows the general form of the cornea, front view, in astigmatism with the rule.

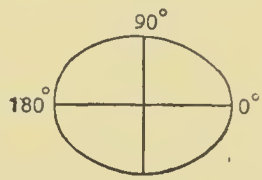


FIG. 19. — Showing front view of an eye with astigmatism with the rule.

We will assume a case with the two chief meridians of curvature at 90° and 180°, exactly.

In such a case the "primary" position would be found (rule 5, p. 17) at 180°. If the inner edges of the images are then approximated and the arc turned 90° to the "secondary" position, the doubled images of the object under measurement cannot become smaller from side to side (the deviation caused by the prism remaining the same), except by overlapping at their inner edges, which they do (see Fig. 8). And the greater the difference in curvature of the two chief merid-

[1] In passing, it may be said that the "primary" position is nothing more than the starting point, or the *first* position in which the lines dividing the mires into halves become straight with each other, showing that one of the two chief meridians of curvature of the cornea has been found. Hence it is called the "primary" or first position. The "secondary" position is at right angles to the "primary" and is called "secondary" simply because it is the second position reached.

ians the more overlapping there will be in astigmatism with the rule.

In astigmatism against the rule, just the reverse holds, that is, the images separate when turned from the primary to the secondary position. A glance at Fig. 20, which represents the general form of the cornea, front view, in astigmatism against the rule, easily explains this.

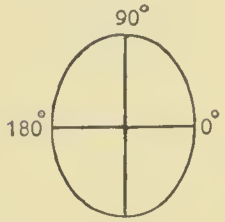


Fig. 20. — Diagram of front view of an eye with astigmatism against the rule showing a vertical oval.

Here the doubled images of the mires are approximated on a meridian with a shorter radius of curvature than the vertical meridian. Consequently, when the images are turned to the secondary position, 90° in this instance, to a meridian with a longer radius of curvature, the images must become larger. But since the deviation caused by the prism is a constant one (2.95 mm.), the doubled images cannot become larger from side to side, except by pulling apart or separating at their inner edges, which they do.

The greater the difference in the radius of curvature of the two chief meridians the greater the separation of the images.

With the above explanation, it is easy to see why the images always overlap when the astigmatism is with the rule and why they always separate when the astigmatism is against the rule. Consequently, when we have an eye under observation with the ophthalmometer, we know immediately, if on turning the arc from the primary position to the secondary position and an overlapping of the images occurs, that we have astigmatism with the rule. If, however, the images separate when the arc is turned from the primary to the secondary position, we know at once that the astigmatism is against the rule.

The instrument, therefore, *says* something and *means* something when the images either overlap or separate. If the images neither overlap nor separate on turning the arc from

the primary to the secondary position, it shows that there is no corneal astigmatism at all. In such cases the patient sometimes takes a weak cylindrical glass (about .50 D.) against the rule, that is, + .50 D. cylindrical axis at 180° or near it, if the patient is hypermetropic; or – .50 D. cylindrical axis 90° or near it, if the patient is myopic. This is explained by the presence of a small amount of lenticular astigmatism which is nearly always present, and against the rule.[1] Consequently we should be on the lookout for this in such cases. Many times, however, when the ophthalmometer shows no corneal astigmatism the patient accepts no cylindrical glass at all.

Why do we deduct half a diopter from the reading of the instrument when the astigmatism is with the rule, and why do we add half a diopter to its reading when the astigmatism is against the rule? The above question is often asked, and perhaps the correct answer and true explanation of same is to be found in the lenticular astigmatism present in most cases.

1. In astigmatism with the rule we usually have to deduct half a diopter from the reading of the instrument, that is, the patient will not accept as much as the instrument gives by .50 D. This can be explained quickest and best by an illustrative case. Say the instrument reads astigmatism *with the rule* 2.50 D., axis 90° + or 180° – . We will assume also, for the sake of simplicity, that it is a case of simple hypermetropic astigmatism. Figure 21 shows a vertical and horizontal section of such an eye and where the rays of light focus. A front view of the cornea and lens is also given in order to show the outlines of their front surfaces. It is evident that, in order to have the rays of light in the vertical meridian focus on the retina, both the cornea and the lens must be emmetropic in the vertical meridian.[2]

[1] Or it may be accounted for by an astigmatism of the posterior surface of the cornea, which sometimes amounts to as much as 1 D.

[2] At least their combined refractive power must be emmetropic in effect.

But the horizontal meridian of the cornea is flatter by 2.50 D. than the vertical meridian, as measured by the instrument; and if the patient had no lenticular astigmatism, it would require a + 2.50 D. cylindrical glass to correct this and bring the rays to a focus on the retina. But as a matter of fact in such a case the patient usually will accept but 2 D. cylindrical glass. This can be explained best, it seems to me, by assuming a lenticular astigmatism, myopic in nature, of .50 D. in the horizontal meridian. This would neutralize that

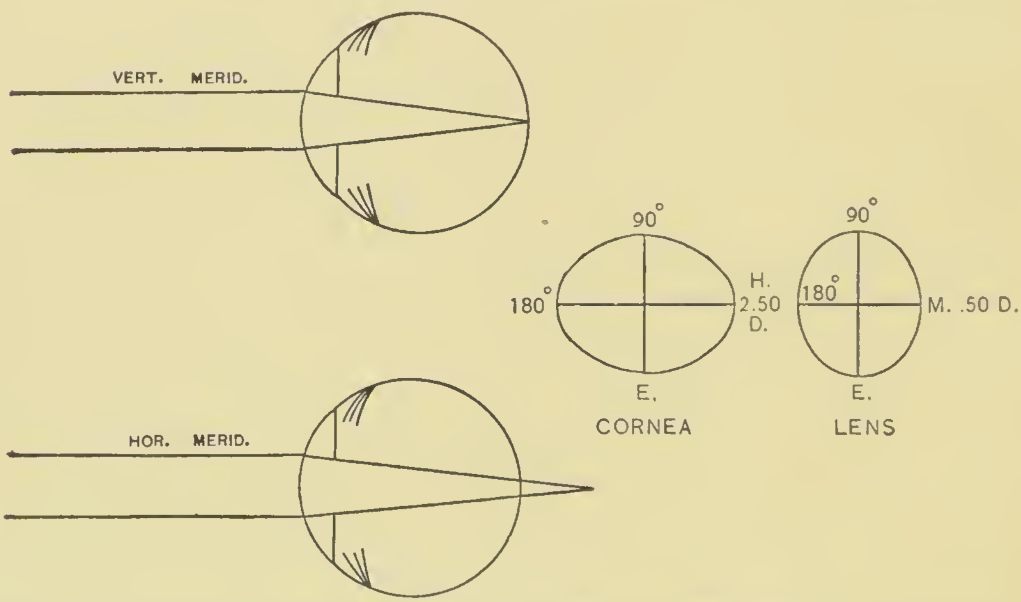


Fig. 21.—Vertical and horizontal sections of the right eye: also front view of the cornea and the lens; simple hypermetropic astigmatism with the rule.

amount (.50 D.) of the hypermetropic corneal astigmatism in the same meridian, leaving but 2 D. of total astigmatism to be corrected by a glass.

What is true in hypermetropic cases is also true in myopic cases; as see Fig. 22.

Here the diagram shows a case of simple myopic astigmatism with the rule 2.50 D. axis 90° + and 180° −. In order to have the rays of light in the horizontal meridian focus on the retina, both the cornea and lens must be emmetropic in the horizontal meridian (that is, their combined refractive power). But the

vertical meridian of the cornea is more curved than the horizontal by 2.50 D. as shown by the ophthalmometer, therefore it would require a – 2.50 D. cylindrical glass, axis 180°, to correct it, if no lenticular astigmatism was present. As a rule the patient will accept but a – 2 D. cylindrical glass. This is to be accounted for by the lens being hypermetropic astigmatic .50 D. in the vertical meridian, thereby neutralizing that amount of the corneal astigmatism, and but 2 D. of total astigmatism is left to be corrected.

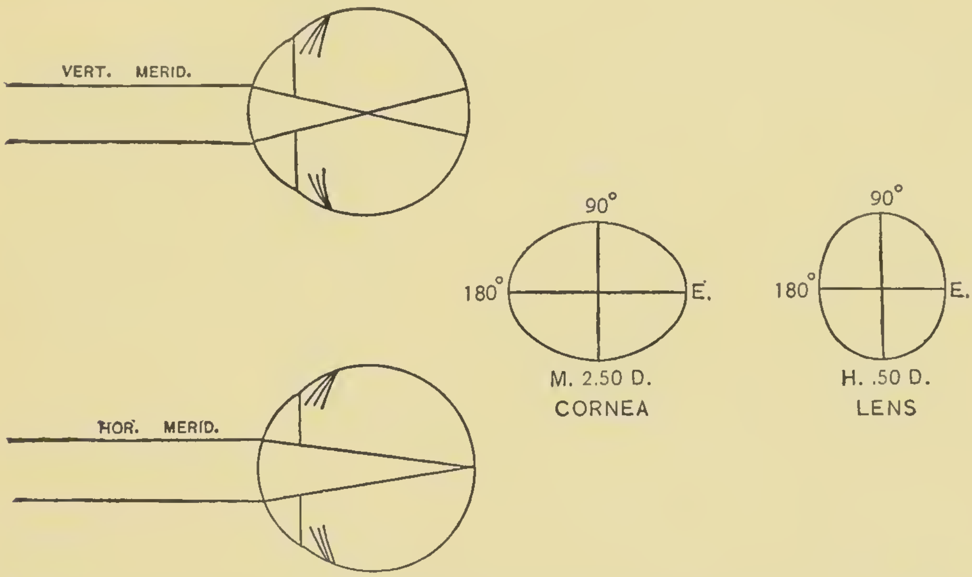


FIG. 22.—Vertical and horizontal sections of the right eye; also front view of the cornea and the lens; simple myopic astigmatism with the rule.

The lenticular astigmatism is not always exactly .50 D., but may be more or less. Sometimes it is only .25 D., or may be absent. Again, it may amount to .75 D., or 1 D., and exceptionally to even larger amounts. As a rule, however, it amounts to .50 D. or .75 D., and in astigmatism with the rule, it being of an opposite kind to the corneal astigmatism, it neutralizes to that extent the corneal astigmatism. And that is why we deduct such amount from the reading of the instrument when the astigmatism is with the rule.

2. In astigmatism against the rule we usually have to add

a half diopter to the reading of the instrument, that is, the patient accepts that much more.

Illustrative cases will serve to explain better than anything else. Say the ophthalmometer reads, astigmatism 2.50 D. against the rule, axis 180° + 90° −. To simplify matters we will assume it to be a case of simple hypermetropic astigmatism.

It is plain from Fig. 23 that both the cornea and lens are emmetropic in the horizontal meridian because the rays of light

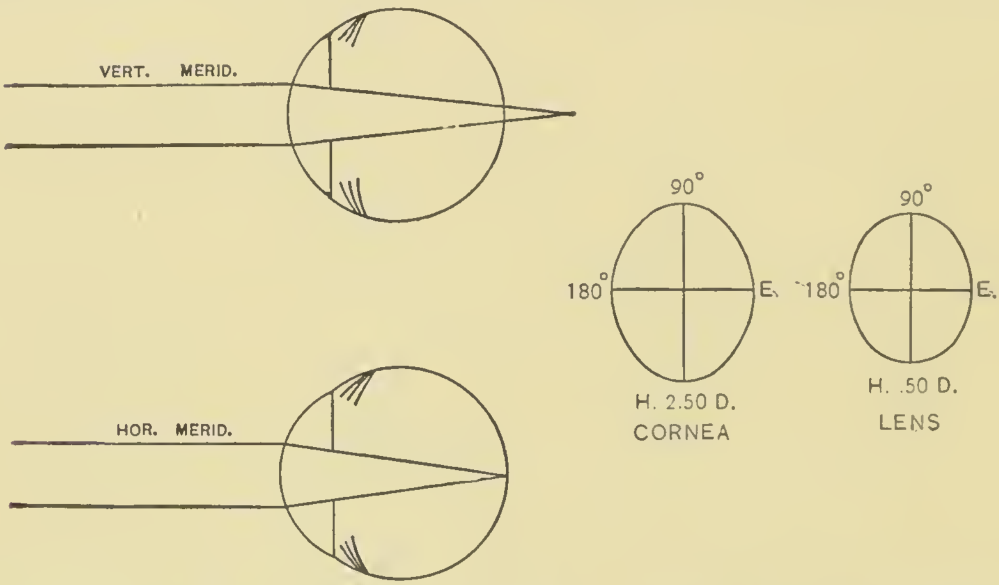


FIG. 23. — Vertical and horizontal sections of an eye with simple hypermetropic astigmatism against the rule; also front view of the cornea and the lens in outline.

passing through this meridian focus on the retina. But the instrument shows the vertical meridian of the cornea to be flatter by 2.50 D. than the horizontal meridian; and if no lenticular astigmatism was present it would take a +2.50 D. cylindrical glass axis 180° to correct same. As a matter of fact, the patient usually accepts a half diopter more than the instrument says. This can be accounted for by a half diopter (.50 D.) of lenticular astigmatism in the vertical meridian, hypermetropic in nature, and, therefore, of the *same* kind as the corneal astigmatism. In other words, both the cornea and lens are hypermetropic in the vertical meridian, the cornea 2.50 D. and the

lens .50 D., the two added together making 3 D. the total astigmatism, consequently it requires a + 3 D. cyl. axis 180° to correct same.

The same law holds true in myopic cases.

Many times, however, in astigmatism against the rule, the patient accepts exactly the glass indicated by the ophthalmometer, showing that lenticular astigmatism is often entirely absent in such cases.

The whole of the explanation given above on this question may be summed up in two short sentences.

1. In *astigmatism with the rule* the lenticular astigmatism is in the *same* meridian as the corneal astigmatism, but is of an *opposite* kind, and usually amounts to half a diopter, thereby neutralizing that amount of the corneal astigmatism.

2. In *astigmatism against the rule* the lenticular astigmatism is in the *same* meridian as the corneal astigmatism, is of the *same* kind, and usually amounts to half a diopter, therefore adds that amount to the corneal astigmatism.[1]

Before closing this chapter there is one final point I wish to elucidate, and that is the reading of the ophthalmometer when the two chief meridians of curvature of the cornea happen to be at 45° and 135°, or exactly halfway between 0° and 90° on one side, and 90° and 180° on the other side.

We know that in astigmatism both with and against the rule that the two main meridians of curvature of the cornea are at 90° and 180°, or in their neighborhood. When the meridian at 90° or its neighborhood is the more curved, as it usually is, it is astigmatism with the rule; but if this meridian happens to be less curved it is astigmatism against the rule.

There are certain exceptional cases where the two chief meridians of curvature of the cornea are just halfway be-

[1] I am not unmindful of the fact that the unequal curvature of the *posterior* surface of the cornea can and may modify the astigmatism of the *front* surface of the cornea. I think, however, the lens plays the more important *rôle*.

tween 0° and 90°, and 90° and 180°, that is, exactly at 45° and 135° (see Fig. 24).

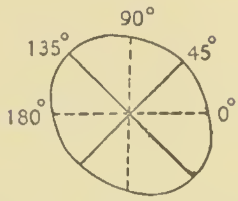


Fig. 24. — Front view of an eye showing the two chief meridians of curvature at 45° and 135°.

Now 45° is no nearer to 90° than it is to 0°, consequently it is not in the neighborhood of one or the other. So with 135° as regards 90° and 180°, it is just as near one as the other, and is not in the neighborhood of either.

What are we to do in such a case as regards "astigmatism with the rule" and "astigmatism against the rule"? Strictly speaking, in such cases, there is no such thing as "astigmatism with the rule" and "astigmatism against the rule," simply because the two chief meridians of curvature are exactly on the halfway mark or dividing lines of what it takes to make astigmatism with, or against, the rule. But how does the ophthalmometer work in such cases? In such cases we search for the primary position as usual (see rule 5, p. 17), by beginning with the long indicator at 0°. We know when we are in the primary position by the two narrow black lines which divide the mires into halves becoming straight with and opposite each other, which they do when either of the chief meridians of curvature of the cornea is reached. In the present case these lines would not be straight when we turned the long indicator to 0°, because neither of the chief meridians is here. Following the directions in rule 5, we turn the long indicator from 0° toward 135°, when 135° is reached (one of the chief meridians of curvature in this instance) the narrow black lines dividing the mires become straight with each other. This is the primary position. We then approximate the images and turn the arc at right angles to the primary position (the long indicator to 45°) to obtain the secondary position. If the meridian at 45° proves to be more curved than the one at 135° the images will overlap.

According to the language of the instrument, that is, when overlapping oeeurs, it means astigmatism with the rule, this would be a ease of astigmatism with the rule. Though, as a matter of faet, we know and have just explained above, that there is really no sueh thing as astigmatism with or against the rule, when the ehief meridians of eurvature are at 45° and 135°. However, for the sake of uniformity of expression and to make the words of the instrument *overlapping* and *separation* of the images mean a definite something in *every case*, it is well to apply the terms "astigmatism with the rule" and "astigmatism against the rule," even to the meridians at 45° and 135°.

It is altogether important also in sueh eases to take either 135° or 45° — one or the other — always as the primary position, and not first one and then the other as the primary position. A glanee at Fig. 24 will show why this is necessary. If we start at 135° as the primary position, the meridian of longest radius of curvature, and then turn to 45°, the seeondary position, to the meridian of shortest radius of curvature, the images will overlap, showing *astigmatism with the rule.* However, should we take 45° as the primary position, the meridian of shortest radius of curvature, and then turn to 135°, at right angles, a meridian with the longer radius of eurvature, the images would separate, showing thereby *astigmatism against the rule.* In other words, the instrument would say astigmatism with the rule and against the rule, *in the same eye*, aeeordingly as we assumed 135° or 45° as the primary position. As we eannot very well have astigmatism both with and against the rule in the same eye, it is best, in such cases as the above, to assume one or the other of these meridians *always* as the primary position. Individually, and in the rules which I have formulated for the use of the instrument, I assume 135° always as the primary position in sueh eases. The meridian at 45° eould be taken just as well, provided it was always taken as the starting or primary position.

CHAPTER III

GENERAL CONSIDERATIONS IN THE USE OF THE OPHTHALMOMETER—SIMPLE HYPERMETROPIC ASTIGMATISM—SIMPLE HYPERMETROPIA—ILLUSTRATIVE CASES

It is well to state here that the ophthalmometer does not, except in an indirect way, which is not at all reliable, indicate the nature of the error of refraction, that is, if it is hypermetropic or myopic in character. All that it does is to measure the front surface of the cornea. If the cornea is uniformly curved in all of its meridians, the instrument shows it by the images of the mires not overlapping or separating in any position after they have once been brought in apposition. If the cornea is not uniformly curved,[1] that is, if astigmatism is present, it measures the difference in the radius of curvature of the two chief meridians, thereby measuring the *amount* of the astigmatism; and also indicates the *position* of these two chief meridians. Of the nature of the error, if hypermetropic or myopic, we have to find out by the use of the trial lenses, the ophthalmoscope, the retinoscope, and at rare intervals we may be obliged to use atropine or some other mydriatic in addition; for, as above stated, the ophthalmometer points to the nature of the error only in an indirect way, as follows: for example, say we find the primary position at 0° or 180°, and that when the images of the mires just touch in this position that the radius of curvature on the cornea in this meridian is just

[1] Of course it is a well-established fact that the cornea is slightly elliptical in shape, but when the images of the mires neither overlap nor separate at any meridian on the cornea after once approximated, we may say it is spherical in shape.

7.8 mm., which is the average radius of curvature of a normal cornea. By noticing the position of the graduated mire in its relation to the millimeter marks on the anterior edge of the arc, in such a case, it will be seen that the fine mark or line on the base of the mire stands just at 7.8 mm. Say now we turn the arc to the second position and the images overlap five steps. This would show that the vertical meridian was more curved than the horizontal, and to the extent of 5 diopters. If, then, in this position the images are withdrawn from their overlapping, so that they just touch again, it will be found that the fine mark on the graduated mire stands opposite, or nearly so, the 7 mm. mark, showing a shorter radius of curvature in this vertical meridian.

Since the horizontal meridian had the normal radius of curvature, the vertical meridian with a shorter radius of curvature would indicate, indirectly to be sure, myopic astigmatism in the vertical meridian. On the other hand, had one found the horizontal meridian with a considerable longer radius of curvature than the average, say 8.5 mm., and then on turning to the vertical meridian, or second position, we found the radius of curvature in this meridian to be just 7.8 mm., the average radius of curvature, we might assume that the horizontal meridian in this instant was hypermetropic in nature on account of its long radius of curvature, 8.5 mm.

Valk, in an examination of over five hundred corneæ with the ophthalmometer, found the average normal radius of curvature to be only 7.65 mm., a considerable shorter radius than is commonly accepted as the average (7.8 mm.).

Proceeding on this assumption, he draws the following conclusion from his examination of cases : —

"That the radius of curvature bears a certain definite relation to the refractive condition of the eyes, in which, if we find that the radius of curvature is greater than 7.65 mm., that the refraction is probably hypermetropic, as we find only one in

ten myopic; on the other hand, if the radius of curvature is less than 7.60 mm., that the refraction is myopic, as now the proportion is found to be one in three."[1]

In this conclusion he differs from almost all other observers. Donders[2] long ago made similar measurements, and came to the conclusion that there was no *definite relation* between the radius of curvature of the cornea and the refractive condition of the eye. He says: "*A priori* it might be supposed, and it has been not only supposed, but also asserted, that less convexity of the cornea and of the crystalline lens is peculiar to the hypermetropic eye. So far as the cornea is concerned, I am justified by the results of numerous accurate determinations, in denying the assertion. Even in high degrees of H., the radius in the visual line (compare p. 89) is nearly equal to that in the emmetropic eye; in the highest degrees, when the circumference of the cornea is somewhat less than usual, I found the radius even less."[3]

The same author draws a similar conclusion in regard to myopia, that is, that the radius of curvature of the cornea bears no definite relation to the refractive condition present.

In extreme degrees of myopia, on the contrary, a somewhat flatter cornea is met with.[4]

He, of course, admits such a thing as *curvature* myopia and hypermetropia, but his ultimate conclusion is, "That *myopia usually depends upon an elongation, and hypermetropia upon a shortening, of the axis of vision.*" All subsequent observers have confirmed this view.

Schiötz[5] also has made special investigation with the ophthalmometer as to the corneal curvature in cases of hypermetropia,

[1] *Ophthalmic Record*, June, 1897.

[2] *Accommodation and Refraction of the Eye*, pp. 88, 89, 246.

[3] *Ibid.*, p. 246.

[4] *Ibid.*, p. 88.

[5] Cited by A. Javal, Jr., *System of Diseases of the Eye*, Norris and Oliver, Vol. II, p. 127.

myopia, and emmetropia, but found no definite law or relation to exist.

A. Javal,[1] in commenting on this subject, says : —

"It is, in fact, remarkable how greatly the radius of curvature may vary for the same refractive condition. In emmetropia the radii of curvature as measured by Schiötz varied between the limits 8.657 mm. and 7.243 mm., or, in diopters, between 38.8 D. and 45.3 D., — a difference of not less than 6.5 D.

"From these figures it would appear that variations in the radius of corneal curvature do not play any great *rôle* in determining the refraction.

"A still more conclusive proof is afforded by observations made on antimetropes. As a rule, in such persons we find the same radius of corneal curvature in both eyes, even when one of these eyes is highly myopic."

I must say that my experience has been that of the great majority of observers, in not finding any definite relation to exist between the radius of corneal curvature and the refractive condition of the eye. And even if the *definite relation* that Valk claims existed, it would be of no value in the fitting of glasses. For under the most favorable circumstances, that is, where the radius was found by the ophthalmometer to be less than 7.60 mm., myopia was absent in $66\frac{2}{3}$ per cent of the cases; while in the most unfavorable conditions, that is, where the radius was over 7.65 mm., it was absent in 90 per cent of the cases. Therefore on an average it failed in 78 per cent of all cases, or was right in but 22 per cent of cases. When it is remembered that myopia forms 16 to 20 per cent of *all* refractive cases, take them as they come, it will be seen of what little value Valk's *definite relation* of corneal radius to the existing refractive condition amounts to.

The ophthalmometer then shows the presence or absence

[1] *Loc. cit.*

of astigmatism; if present, whether it is with or against the rule, the amount, and the axes of the main meridians. It does not, except in a very indefinite way, as just pointed out above, indicate the character of the error of refraction, whether hypermetropic or myopic. This latter point, in the great majority of cases, is easily determined, and most of the time by the simple subjective test with the test cards and trial lenses, that is, if the test is begun properly. If not revealed by the trial lenses, then further objective tests with the ophthalmoscope and retinoscope will reveal the nature of the error, except in a very limited number of cases in subjects under twenty years of age, when a mydriatic must be called into requisition.

In my practice, both private and hospital, I do not use a mydriatic in more than one per cent of all cases of refraction. And I may say here, that I agree with my illustrious teacher and preceptor, D. B. St. John Roosa, on this point, that it is not necessary to use atropine or mydriatics of any kind, except in rare instances.[1] The soundness of this practice is amply borne out in my private practice and in the clinic at the Manhattan Eye and Ear Hospital. In 1891 I took all the cases of refraction consecutively that came to the clinic of Drs. Roosa and Lewis, and found that a mydriatic was used but once in every sixty-four cases, or in about 1.5 per cent of all cases of refraction. In 1896, in the same clinic for a period of six months, atropine was not used in a single case uncomplicated with squint.[2]

In squint cases it is advisable to use a mydriatic so as to give a full, or almost full, correction of the error of refraction, and in that way aid in straightening the eye. But in ordinary uncomplicated cases of refraction, I repeat, it is rarely necessary or advisable to use any mydriatic whatever. Furthermore, it

[1] Hirschberg, George J. Bull, Dennett, and many others hold the same opinion as to the use, or rather non-use, of mydriatics.

[2] D. B. St. John Roosa, *Manhattan Eye and Ear Hospital Report*, 1896.

may be remarked that since we have used the ophthalmometer at the Manhattan Eye and Ear Hospital clinics, and depended on it almost to the exclusion of atropine, that we have changed fewer glasses than formerly, when atropine was used in nearly every case under forty years of age. The same holds true in my private practice. .

When we take into account the time and great annoyance saved to the patient by not using atropine, we can readily see the advantages of an ophthalmometer. In fact, many business men will not tolerate a mydriatic; and one can hardly blame them when it is known that their eyes can be tested, with rare exceptions, just as well or better without atropine than with it.

If the following routine of examination, which I shall now give, is followed out, 99 per cent of all uncomplicated cases of error of refraction can be fitted without the use of mydriatics.

1. Use the ophthalmometer.
2. Use trial lenses and test cards.
3. Use the ophthalmoscope.
4. If after two tests on different days the result is still unsatisfactory, employ a mydriatic and use the retinoscope in addition to the other tests.

The reason that I do not, as a rule, use the ophthalmoscope before testing with the trial lenses is that if light is thrown into the eye for a prolonged time, it dazzles the sight and impairs the value of an immediate test with the trial lenses. If I have much trouble, however, in finding the proper glass, I do not hesitate to use the ophthalmoscope to find the nature of the error of refraction, or if any pathological condition of the eye exists ; then let the patient wait a short while before the subjective test with the trial lenses is again undertaken.

Simple cases of hypermetropia and myopia are, as a rule, easily fitted to glasses ; but a certain definite method should be followed even in these cases. It is the astigmatic cases that give most trouble, and among these, as is well known, the

compound hypermetropic and mixed astigmatisms are the most difficult to fit.

Astigmatism is the thing of most importance in correcting errors of refraction, and I invariably correct the astigmatism first, unless there is a large amount of spherical error present — a myopia of 8 diopters or more, or a hypermetropia of 6 diopters or more — with only a small amount of astigmatism. In such cases, part of the spherical error is first to be corrected, in order, if possible, to bring up the vision sufficiently, so that the eye will appreciate any further change in acuity of vision when a weak cylindrical glass is placed in front of it.

I always begin my test by putting on *plus* glasses; plus cylindrical glasses if astigmatism is present, plus spherical glasses if astigmatism is absent, and for the following reasons: First, because we do not know if the patient is hypermetropic or myopic. If the patient happens to be hypermetropic, plus glasses are accepted, as a rule, if begun with; however, if minus glasses are first tried, the patient many times accepts them, especially if the error is of low amount, though the patient is really hypermetropic. This fact is so well known that it is hardly necessary to more than merely allude to it. The eye instinctively makes an effort to overcome minus glasses when placed in front of it, the ciliary muscle is thrown into a spasm of accommodation, producing an artificial myopia, which the minus glass partly or wholly corrects, and in this way apparently improves vision. The mere fact that a patient accepts minus glasses is no indication whatever that he has myopia. Furthermore, minus glasses should never be tried until plus glasses have been tried, unless we know beforehand that the patient is really myopic, for they tend to incite a spasm of accommodation, which is the very thing we wish to avoid.

The thing of next importance to plus glasses in beginning a test is that we shall begin with the *weakest* lenses in the trial case, and go up gradually. I do this also to avoid spasm of

accommodation, for by adding a quarter of a diopter at a time the eye accustoms itself to it, and the ciliary muscle relaxes gradually if it is only given a chance.

Should all, or almost all, of the correction be put on at once, however, the change for the eye is so sudden and marked that it will not adjust itself to it; whereas, had the glasses been gradually increased in power, the ciliary muscle would have relaxed. This is my experience, and I believe it accords with that of the great majority of observers.[1]

By following this plan, spasm of accommodation, if present, can, in the great majority of cases, be overcome, and if not present, the liability of causing it be avoided.

Another method of avoiding spasm of accommodation, and one well known among oculists, is to correct both eyes at the same time.

Not only do I follow the above routine, but under step No. 2 I follow a certain routine in putting the glasses in the trial frames during the subjective tests. Bearing in mind always to begin the test with a *plus* glass (unless we know beforehand the patient to be myopic), and a *weak* plus glass, and to gradually increase the strength of the glass, in order to avoid or overcome spasm of accommodation, I proceed in the following manner: When the ophthalmometer indicates astigmatism, first try plus cylindrical glasses alone; second, plus spherical glasses in addition; third, minus cylindrical glasses at right angles to the plus cylindrical glass, if vision is not made perfect[2] by a

[1] Some oculists, however, resort to putting on very much too strong plus glasses, which blur the vision completely, and in that way take away the desire to accommodate for or fix on any object. Then, by gradually diminishing the power of the glass, the correct glass is finally accepted. For myself, I much prefer to begin with the weakest, and work up.

[2] For instance, if the ophthalmometer should indicate 4 diopters of astigmatism, with the rule, 90° + or 180° −, and the patient would accept only + 2 D. cyl. axis 90°, with improvement of vision, but would accept no plus spherical glass in addition, mixed astigmatism is at once suspected, and minus cylindrical glasses are tried at right angles to the plus cylinder.

plus cylindrical glass alone, and plus spherical glasses are not accepted in addition ; fourth, minus cylindrical glasses alone ; fifth, minus spherical glasses in addition.

When the ophthalmometer indicates but one-half a diopter of astigmatism with the rule, usually the lenticular astigmatism neutralizes that amount of corneal astigmatism, and the patient will not accept any cylindrical glass. In such cases we are most of the time dealing with cases of simple hypermetropia and myopia, and proceed at once to try plus spherical glasses, and, if not accepted, minus spherical glasses. However, should there be only a very small amount of hypermetropia or myopia, and the patient's sight is not improved by the spherical glasses, it is well to try a weak cylinder, plns first, then minus. This is for two reasons: first, we may have made an error with the ophthalmometer in the estimation of the amount of the astigmatism ; second, the lenticular astigmatism might not be sufficient to neutralize the half diopter of corneal astigmatism, or it might more than neutralize it, when it would result in a small amount of astigmatism against the rule.

It has been maintained by some authorities that the ophthalmometer is not of value in cases of simple myopia and hypermetropia, an opinion from which I beg to differ. In cases of hypermetropia and myopia it eliminates the question of corneal astigmatism. This is a very important factor, for with no astigmatism present the tests for glasses are usually very easily made. The ophthalmometer is of great value in a negative way, therefore, even in cases of simple hypermetropia and myopia.

Illustrative cases of simple hypermetropic astigmatism and hypermetropia. — In giving illustrative cases I shall first take a typical case, giving the tests for its detection and correction in detail ; then other cases showing different amounts of astigmatism and different axes, and cases against and with the rule will be taken. In many cases diagrams of the sections of the eye under observation through its two chief meridians of cur-

vature are given.[1] This is done in order to have the reader think of the eye *as it is*, to see where the rays of light entering such an eye focus, and how the proper glasses correct the error of refraction in such a case. It has been my experience that students at least do not think of the eye under observation, but try to fit the patient to glasses by following some rule in a book. They put the glasses on empirically; if they improve vision, very well, they are satisfied with that and do not worry themselves much about the why or the wherefore; if the glasses do not improve vision, they are at a loss to know why, and many times give a wrong glass. Beginners, especially, are in doubt in cases where there is marked amblyopia present, where a patient will accept even a strong plus glass without improvement in vision. This is a common occurrence in cases of convergent squint, where, as is well known, usually a large amount of hypermetropia is present, especially in the squinting eye. Though there may not be any lesion of the fundus in either eye, the squinting eye is usually very weak-sighted or amblyopic, and will accept plus glasses without improvement in vision, or with only very slight improvement. It is very important that such an eye should have the right glass, yet, if the examiner is not sure of the correctness of his examination and correctly informed in optics, he might hesitate as to giving the glasses on account of the lack of improvement in vision. It is in just such cases of amblyopia, especially when the amblyopia happens to be in the case of a child or an ignorant person, that the ophthalmometer is of such great advantage.

Case I. *Corneal astigmatism with the rule,* 1 *D., axis* 90° + *or* 180° – ; *Patient accepts* + .50 *D. cyl., axis* 90°. — April 6, 1892, Nellie H., aged twenty-three years, in good general health, has had trouble with her eyes for about two years. After any continuous work, especially at night, her eyes burn

[1] These diagrams are not meant to be mathematically correct, and are used simply to make the subject matter plainer.

and ache, and often headaches follow. There is some redness of the edges of the eyelids and congestion of the conjunctiva.

Ophthalmometer. — Astigmatism with the rule, 1 D., axis 90° + or 180° − in each eye.

Figure 25 shows the general shape of the cornea, front view, in this case. Since the astigmatism is with the rule, the vertical meridian must be more curved, that is, have a shorter radius of curvature than the horizontal.

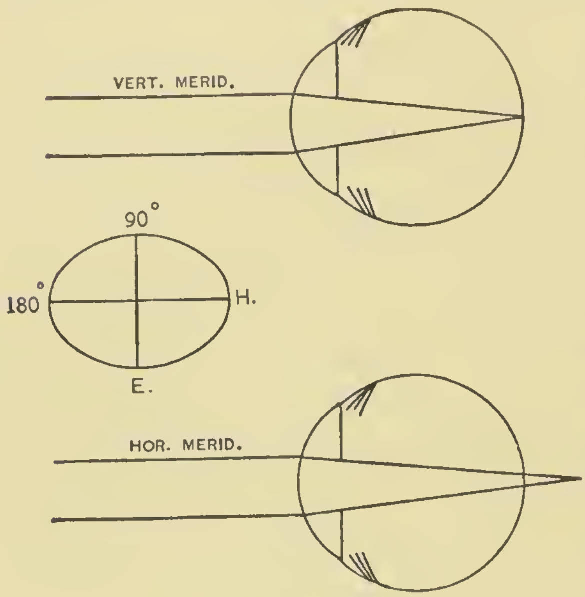


Fig. 25.

We do not know, however, from the examination with the ophthalmometer whether the error of refraction is hypermetropic or myopic in character — that must be found out by subsequent tests.

Unless from the history of the case I have reason to suspect some pathological lesion of the eye, I next try the trial lenses and test cards. I do this, first, for the very good reason that most cases reveal the nature and extent of the error of refraction simply by the use of the ophthalmometer and trial lenses; second, because we do not have to delay the test with the trial lenses as we do where the ophthalmoscope is first used, for the light thrown into the eye by an extended ophthalmoscopic examination dazzles the eye and requires some delay afterward before the subjective test can be completed.

Test cards and trial lenses.—The horizontal lines on Green's clock dial were seen plainest in this case.

R. V. = $\frac{20}{20}$ − : $\frac{20}{15}$ W. + .50 D. cyl., 90°.

L. V. = $\frac{20}{20}$ − : $\frac{20}{15}$ W. + .50 D. cyl., 90°.

Reads Jaeger No. 1 from 6 to 15 inches.

Bearing in mind to correct the astigmatism first, if any is present, and proceeding with the test, as directed on page 42, by beginning with a weak plus glass, the first glass tried was + .25 D. cyl., 90° (as indicated by the ophthalmometer). This improved vision somewhat, so the next stronger cyl., + .50 D., axis 90°, was tried; this improved vision still more. The next stronger cyl., + 75 D., axis 90°, made the vision worse. A + .50 D. cylindrical glass then was the strongest cylinder that gave the best vision. To see if any manifest hypermetropia was present in addition to the astigmatism, + .25 D. spherical glass was placed in front of the + .50 D. cylindrical glass; it made vision worse, showing no manifest hypermetropia to be present.

The same mode of procedure was followed in the left eye, the patient accepting a + .50 D. cylindrical glass, axis 90°, and obtaining the best vision, $\frac{20}{20}$ in each eye.

Ophthalmoscope. — Hypermetropic astigmatism with the rule, .50 D., axis 90°, in each eye; no pathological lesion of the fundus in either eye.

The patient accepted the same glass on the second test, two days later and + .50 D. cyl., axis 90°, was prescribed for each eye.

The retinoscope and mydriatics were not used in this case, as they were not deemed necessary. A mild astringent wash was prescribed for the slight inflammation of the lids. October 17, 1895, three and a half years later, the patient returned on account of a slight conjunctivitis. With mild astringents this was cured in three weeks' time. The glasses were still satisfactory.

CASE II. *Astigmatism with the rule*, 4 *D., axis* 10°, *to the temporal side of the vertical meridian in each eye; Patient complains of no asthenopia, but simply of poor vision; Accepts* 3.50 *D. cyl. in each eye.* — December 5, 1894, O. M., aged twenty-six years, in robust health, consulted me on account of poor

vision. The remarkable thing about this case is that the patient never complained of asthenopia, though the tests showed him to have such a high degree of hypermetropic astigmatism. He never saw well, and noticed at school that he could not see as well as his companions. At night he could not read ordinary print.

Ophthalmometer. — Astigmatism with the rule, 4 D., axis 100° + or 10° – right eye; 4 D., axis 80° + or 170° – left eye.

Test cards and trial lenses. —

$$\text{R. V.} = \tfrac{20}{200} : \tfrac{20}{40} \text{ W.} + 3.50 \text{ D. cyl., } 100°.$$

$$\text{L. V.} = \tfrac{20}{200} : \tfrac{20}{50} \text{ W.} + 3.50 \text{ D. cyl., } 80°.$$

Reads Jaeger No. 1 from 4 to 12 inches.

Ophthalmoscope. — Simple hypermetropic astigmatism in each eye. Two days after the first test a second test was made, and the patient accepted the same glass, which was ordered. The patient was seen two years later and the glasses were satisfactory.

CASE III. *Corneal astigmatism with the rule .50. D., neutralized by lenticular astigmatism; Patient accepts simple plus spherical glass.* — October 3, 1893, M. B. H., aged thirty-three, general health is very good, but she is not robust. She complains of headaches and blurring of vision when she reads. The patient has worn glasses for the last two years, but without benefit.

Ophthalmometer. — Astigmatism with the rule, .50 D., axis 90°+ or 180° – each eye.

Test cards and trial lenses. — All of the lines on the clock dial are seen with equal clearness.

$$\text{R. V.} = \tfrac{20}{30} + : \tfrac{20}{15} \text{ W.} + 2.75 \text{ D.s.}$$

$$\text{L. V.} = \tfrac{20}{40} + : \tfrac{20}{20} \text{ W.} + 3.75 \text{ D.s.}$$

Reads Jaeger No. 1 at 6 inches.

Ophthalmoscope. — H. 3 D. right; H. 4 D. left, with normal fundi.

It will be observed in the above case that although the ophthalmometer showed corneal astigmatism of half a diopter with the rule, axis 90° + or 180° –, that the patient did not accept any cylindrical glass.

Following the rule laid down by Javal, and since confirmed by many observers, that when the instrument reads astigmatism "with the rule" .50 D. usually must be subtracted from the reading, it will be seen that no astigmatism is left for correction in the above case. As fully explained, page 29, the lenticular astigmatism (or the action of the lens?) in such cases is in the same meridian as the corneal astigmatism, amounts as a general thing to .50 D., and is of an opposite kind[1] to the corneal; therefore it neutralizes the corneal astigmatism just to that extent.

Sometimes the lenticular astigmatism amounts to but .25 D., and sometimes it is entirely absent. Again, it may amount to a whole diopter or a diopter and a half, and in very exceptional cases to even more. So constant, however, is the lenticular astigmatism of .50 D., that, when we find that the patient does not accept the cylindrical glass as indicated by the ophthalmometer to within .50 D., it is well to take a second, a third, and even a fourth reading with the instrument, to see if we have not really made an incorrect reading. From my own experience I would say that the lenticular astigmatism generally amounts to just .50 D., next to this to .25 D., next to this .75 D., and next to this 1 D.

CASE IV. *Corneal astigmatism with the rule, .25 D., neutralized by the lenticular astigmatism; Patient accepts simple spherical glasses.* — I. W. S., aged twenty years, general health

[1] That is, if the horizontal meridian of the cornea is less curved by .50 D. than the vertical meridian, then the horizontal meridian of the lens is more curved by .50 D. than the vertical meridian.

first class. He is a hard student; his eyes ache and the vision blurs in the afternoon and evening.

Ophthalmometer. — Astigmatism with the rule, .25 D., axis 90° + or 180° − in each eye.

Test cards and trial lenses. —

$$\text{R. V.} = \tfrac{20}{20} : \tfrac{20}{15} \text{ W.} + .50 \text{ D.s.}$$
$$\text{L. V.} = \tfrac{20}{20} : \tfrac{20}{15} \text{ W.} + .50 \text{ D.s.}$$

Reads Jaeger No. 1 at 6 inches.

Ophthalmoscope. — Hypermetropia 1 D. each.

As this patient was from a neighboring state and had to return, I ordered glasses after one test, +.50 D.s, for each eye. They relieved his headaches and painful vision, and he was able to finish his schooling.

In this case the corneal astigmatism of .25 D. was exactly neutralized by a lenticular astigmatism of .25 D.; the lenticular not amounting to its usual .50 D., in which case it would have over-neutralized the corneal astigmatism of .25 D.

Case V. *Corneal astigmatism with the rule, .25 D., with no lenticular astigmatism.* — Sometimes the patient accepts the exact amount of astigmatism indicated by the ophthalmometer, even when the astigmatism is with the rule. This shows that in some instances there is no lenticular astigmatism at all, but only corneal. The present case illustrates this.

March 2, 1892, Catharine H., aged twenty years, is in good health, but her eyes have been weak since a child; she has had many styes, and the eyelids are red most of the time. There is a well-marked *blepharitis marginalis* now. Typical asthenopia.

Ophthalmometer. — Astigmatism with the rule, .25 D., axis 90° + or 180° − in each eye.

Test cards and trial lenses. —

$$\text{R. V.} = \tfrac{20}{15} : \tfrac{20}{15} + \text{W.} + .25 \text{ D. cyl., } 90°.$$
$$\text{L. V.} = \tfrac{20}{15} : \tfrac{20}{15} + \text{W.} + .25 \text{ D. cyl., } 90°.$$

Reads Jaeger No. 1 at 4 inches.

Ophthalmoscope. — Hypermetropia .50 D. each.

A solution of boracic acid was given to cleanse the eye with twice a day, and a weak ointment of yellow oxide of mercury to rub on the lids at night, although she stated that she had used this same ointment before without effect.

Two days after, she was tested a second time and accepted the same glass as on the first test. The lids were in about the same condition as when first seen. A plus .25 D. cylindrical glass, axis 90°, was ordered for each eye. With these glasses the redness of the lids were entirely relieved, the styes ceased to return, and she used her eyes with comfort.

While this case is reported primarily to show that there may be only corneal astigmatism present, and in a very small amount, it incidentally shows the value of very weak cylindrical glasses in some cases. It is well known that weak cylindrical glasses (.25 D.), when worn against the rule or at slanting axis, often give marked relief, but they sometimes are of great benefit when worn with the rule and at symmetrical axis, as shown in the present case.

The ophthalmometer is of the greatest service in fitting correctly such cases.

CASE VI. *Corneal astigmatism with the rule*, .50 *D.*, *with no lenticular astigmatism.* — December, 1896, Ruth M., aged twenty-six, is in robust health, but the eyes pain and the vision blurs when she sews or reads for a little time.

Ophthalmometer. — Astigmatism with the rule, .50 D., axis 90° + or 180° − in each eye.

Test cards and trial lenses. —

$$\text{R. V.} = \tfrac{20}{30} : \tfrac{20}{15}\ \text{W.} + .50\ \text{D. cyl., } 90°.$$

$$\text{L. V.} = \tfrac{20}{30} : \tfrac{20}{15}\ \text{W.} + .50\ \text{D. cyl., } 90°.$$

Reads Jaeger No. 1 at 7 inches.

Ophthalmoscope. — Emmetropia in the vertical meridian, and hypermetropia of .50 D. in the horizontal meridian.

On a second test the same glass was accepted and prescribed, which gave satisfaction.

Case VII. *Corneal astigmatism with the rule, 1 D. right eye and .75 D. left eye; No lenticular astigmatism.* — G. W. G., aged thirty-five years, general health good. He has worn glasses for four or five years, but not with comfort. Styes have troubled him from time to time also in the last four years.

Ophthalmometer. — Astigmatism with the rule, 1 D., 105° + 10° − right eye; .75 D., 75° + or 165° − left eye.

Test cards and trial lenses. —

R. V. = $\frac{20}{50}$: $\frac{20}{20}$ W. + .75 D. cyl., 105°.

L. V. = $\frac{20}{40}$: $\frac{20}{20}$ W. + .75 D. cyl., 75°.

Reads Jaeger No. 1 at 7 inches.

Ophthalmoscope. — Simple hypermetropic astigmatism with the rule, 1 D. each, axis 105° right and 75° left.

Second test; the ophthalmometer showed the same reading, the axis in the right eye being two or three degrees nearer to the vertical meridian perhaps.

Test cards and trial lenses. —

R. V. = $\frac{20}{50}$: $\frac{20}{20}$ + W. + 1 D. cyl., 105°.

L. V. = $\frac{20}{40}$: $\frac{20}{20}$ + W. + .75 D. cyl., 75°.

This last glass was ordered, but in about three months' time the axis of the right glass had to be shifted from 105° to 100°, a distance of 5°, when the glasses gave perfect comfort, and continued to do so for the next few months that the patient was under observation.

Case VIII. *Corneal astigmatism with the rule, 1 D., with no lenticular astigmatism; Presbyopia.* — Mrs. T. R., aged fifty-three, in moderately good health. She began to wear glasses seven years ago, but they have never given her comfort, her eyes paining her when she sews or reads.

Ophthalmometer. — Astigmatism with the rule, 1 D., axis 90° + or 180° – in each eye.

Test cards and trial lenses. —

R. V. = $\frac{20}{30}$: $\frac{20}{15}$ W. + 1 D. cyl., 90°.

L. V. = $\frac{20}{30}$: $\frac{20}{20}$ W. + 1 D. cyl., 90°.

Reads Jaeger No. 1 at 8 inches with + 3 D. spherical glass added for the presbyopia. + 3 D.s + 1 D. cyl., 90° was ordered for each eye for reading. These glasses have given her entire satisfaction for almost three years.

The last four cases reported are somewhat out of the ordinary, because of the absence of lenticular astigmatism. Furthermore, they serve to show the necessity of testing for any astigmatism that the ophthalmometer indicates, for it may be the only form of astigmatism present.

Case IX. *Hypermetropic astigmatism against the rule*, 1 *D. right eye*, .75 *D. left eye; Patient accepts* .50 *D. more than the instrument reads.* — L. M.,[1] aged thirty-nine, general health good. Her eyes have not given her any special trouble until the last year, when they began to pain her and the vision to blur when she read or sewed for any great length of time. At night she had to give up close work and reading.

Ophthalmometer. — Astigmatism against the rule, 1 D., axis 180° + or 90° – right eye; .75 D., axis 180° + or 90° – left eye.

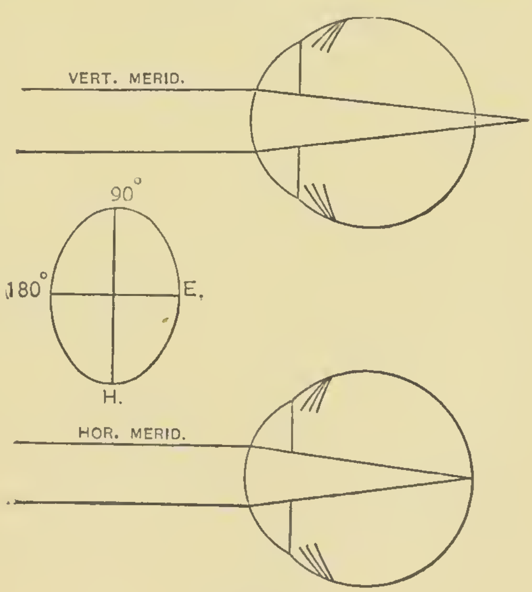


Fig. 26.

Figure 26 is a diagrammatic section of such an eye showing where the rays of light

[1] Reported from Drs. Lewis and Van Fleet's clinic.

focus respectively in the vertical and horizontal meridians. The horizontal meridian is emmetropic and focusses rays on the retina; while the vertical meridian is hypermetropic, less curved than the horizontal, and allows the rays of light to focus back of the retina.

Test cards and trial lenses. — The vertical lines on the Green's clock-dial are seen plainest.

R. V. = $\frac{20}{40}$: $\frac{20}{30}$ + W. + 1.50 D. cyl., 180°.

L. V. = $\frac{20}{30}$: $\frac{20}{20}$ + W. + 1.25 D. cyl., 180°.

Ophthalmoscope.—Simple hypermetropic astigmatism against the rule.

On a second test the same glasses were accepted by the patient and were ordered. The above glasses have been worn for three years with perfect satisfaction. Usually in cases of astigmatism against the rule we add .50 D. to the reading of the instrument. However, it may be more or less, as illustrated by some of the following cases. Furthermore, in the cases of astigmatism against the rule must be reckoned those where there is no corneal astigmatism at all, for in such cases there is usually a small amount of lenticular astigmatism against the rule which must be corrected.

Case X. *Corneal astigmatism against the rule; The patient accepts only .25 D. more than the instrument reads.* — Lawrence M., aged eleven, was seen at the clinic on February 2, 1897. Is in good health, family history good — father died aged forty, from accident, mother living, aged thirty-three, one sister older and two brothers younger living — none ever wore glasses.

Ophthalmometer. — Astigmatism against the rule, .25 D., axis 180° + or 90° — in each eye.

Test cards and trial lenses. —

R. V. = $\frac{20}{20}$: $\frac{20}{15}$ W. + .50 D. cyl., 180°.

L. V. = $\frac{20}{20}$: $\frac{20}{15}$ W. + .50 D. cyl., 180°.

Reads Jaeger No. 1 at 6 inches.

Ophthalmoscope. — Hypermetropia 1 diopter in each eye.

A mild astringent wash was ordered for the lids, which were somewhat inflamed. On a second test, one week later, the patient accepted the same glass as at first. Ordered + .50 D. cyl. 180° each eye. September, 1897, the glasses were still satisfactory.

CASE XI. *Ophthalmometer shows corneal astigmatism against the rule, and the patient accepts .75 D. more than the instrument reads.* — Abbie P., aged forty-six, came to the clinic on December 27, 1892. Has worn glasses for the last six years, but none of them have been satisfactory. She is in fairly good health.

Ophthalmometer. — Astigmatism against the rule, .25 D., axis 180° + or 90° − in each eye.

Test cards and trial lenses. —

$$\text{R. V.} = \tfrac{20}{70} : \tfrac{20}{20} + \text{W. 1 D. cyl., } 180°.$$

$$\text{L. V.} = \tfrac{20}{50} : \tfrac{20}{20} + \text{W. 1 D. cyl., } 180°.$$

Reads Jaeger No. 1 at 10 inches with a + 3 D. added for presbyopia, which is a big amount considering the age of the patient, only forty-six years.

Ophthalmoscope. — Hypermetropic astigmatism.

Two days later a second test gave the same result as the previous one. Ordered + 1 D. cyl., 180° each eye, for distance; and + 3 D.s added for reading. The same strength cylindrical glasses have been worn since, but the spherical part has been increased for the increasing presbyopia.

CASE XII. *Ophthalmometer shows astigmatism against the rule; The patient accepts the reading of the instrument exactly in one eye, but .25 D. less than the reading of the instrument in the other, though the astigmatism is against the rule.* — S. H. W., aged thirty-six, in robust health, consulted me February 5, 1894, on account of painful vision. His eyes have troubled him more or less for over a year, especially for close work.

Ophthalmometer. — Astigmatism against the rule, 1.50 D., axis 180° + or 90° − right eye; .75 D., axis 180° + or 90° − left eye.

Test cards and trial lenses. —

$$\text{R. V.} = \tfrac{20}{100} : \tfrac{20}{40} \text{ W.} + 1.50 \text{ D. cyl., } 180°.$$

$$\text{L. V.} = \tfrac{20}{40} : \tfrac{20}{30} \text{ W.} + \ .75 \text{ D. cyl., } 180°.$$

Reads Jaeger No. 1 at 5 inches.

Ophthalmoscope. — Hypermetropic astigmatism against the rule, 1 D. each eye.

On a second test the ophthalmometer gave the same reading, and the patient accepted exactly the same glass in the right eye, but a .25 D. weaker glass in the left eye. Ordered: —

+ 1.50 D. cyl., 180° right eye;
+ .50 D. cyl., 180° left eye.

May, 1896, over two years after they were ordered, the glasses were still giving entire satisfaction.

Case XIII. *No corneal astigmatism, but the patient accepts a + .50 D. cylindrical glass against the rule, at* 180°. — C. C. D., aged forty-two years, general health is good. He consulted an eminent oculist ten years ago, who told him that he had no refractive error; his eyes continued to trouble him more or less all the time. Nine months ago he had spherical glasses fitted on account of presbyopia, but they have been unsatisfactory. He consulted me first in February, 1893, when the following condition of affairs was found: —

Ophthalmometer. — Shows no corneal astigmatism, that is, the images of the mires neither overlap nor separate at any position after they have once been approximated, and the black lines dividing them into halves remain opposite and straight in all positions.

In such cases it is usual for the patient to have lenticular

astigmatism of about .50 D. against the rule, that is to say, if the eye is hypermetropic that a plus cylindrical glass will be worn with its axis at 180°, or in that neighborhood, while if myopic a minus cylindrical glass will be worn at 90°, or in that neighborhood.

A and *B* in Fig. 27 show the shape of the cornea and lens respectively, and focuses of the two chief meridians combined in the present case. *A* shows both meridians of the cornea to

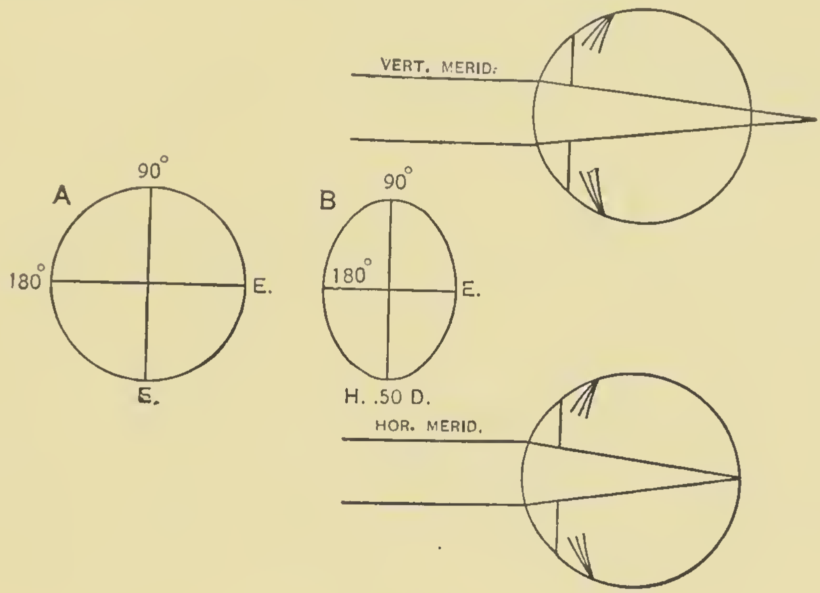


Fig. 27.

have the same radius of curvature, therefore the cornea to be spherical in shape. It is emmetropic in refractive power in this case.

The lens (*B*, Fig. 27) is emmetropic in refractive power in the horizontal meridian also, but in the vertical meridian it is hypermetropic by .50 D.

As both the cornea and the lens are emmetropic in the horizontal meridian, it allows the rays of light that pass through that meridian to focus exactly on the retina. The cornea is emmetropic in the vertical meridian also, but the lens is hypermetropic .50 D., and consequently the rays of light that pass

through that meridian focus behind the retina. It requires a cylindrical glass of .50 D., axis 180°, to focus these rays of light on the retina; and a plus cylindrical glass worn with its axis at 180° shows the astigmatism to be against the rule.

Test cards and trial lenses. —

$$\text{R. V.} = \tfrac{20}{20} - : \tfrac{20}{15} \text{ W.} + .50 \text{ D. cyl., } 180°.$$
$$\text{L. V.} = \tfrac{20}{20} - : \tfrac{20}{15} \text{ W.} + .50 \text{ D. cyl., } 180°.$$

Reads Jaeger No. 1 at 7 inches with a + .75 D. spherical glass added to correct the presbyopia.

Ophthalmoscope. — Hypermetropic astigmatism .50 D. against the rule.

Ordered + .75 D. + .50 D. cyl., 180° each. May, 1895, two years later, the glasses are still satisfactory.

In such cases as the above, and especially in presbyopes, the retinoscope is of value in confirming the subjective tests. In young subjects, however, to make the retinoscopic tests reliable atropine or some mydriatic must be used, which fact impairs its usefulness very much. Fortunately it is seldom necessary to use mydriatics of any kind, and in my practice retinoscopy, or more correctly speaking, *skiascopy*, plays a very unimportant rôle.

Case XIV. *No corneal astigmatism. The patient accepts + cylindrical glasses against the rule at different axes,* 180° *and* 135° *respectively.* — N. V., aged fourteen years, general health first-class, consulted me April 1, 1896. For three months her eyes have troubled her greatly, and especially after studying her lessons. Blurring of the vision, pain in the eyes, and headaches are the chief symptoms she complains of. She has an older sister who has mixed astigmatism.

Ophthalmometer. — No corneal astigmatism.

Retinoscope. — Hypermetropic astigmatism of small amount (.50 D.) in each eye, axis of cylindrical glass 180° Rt., and at 135° (?) Lft.

Test cards and trial lenses. — The vertical lines from XII to VI in the clock-dial are seen plainest in the right eye, while the lines from X to IV and XI to V are seen plainest with the left eye.

$$\text{R. V.} = \tfrac{20}{20} - : \tfrac{20}{15} \text{ W.} + .50 \text{ D. cyl., } 180°.$$

$$\text{L. V.} = \tfrac{20}{20} - : \tfrac{20}{15} \text{ W.} + .50 \text{ D. cyl., } 135°.$$

Reads Jaeger No. 1 at 3 inches.

Ophthalmoscope. — Hypermetropic astigmatism of small amount, but could not be estimated accurately.

Figures 27 and 28 show the form of the cornea and the foci of the chief meridians in the right and left eyes respectively.

On account of a mild conjunctivitis, an astringent wash for the eyes was ordered, and the patient requested to come again in one week. A mydriatic was ordered to be used for three days before coming for the second test. The second test corresponded with the first as to the amount and axis of the astigmatism, but the patient accepted + .75 D. spherical glasses in addition to the cylinders. The ophthalmoscope and retinoscope showed compound hypermetropic astigmatism. Ordered: —

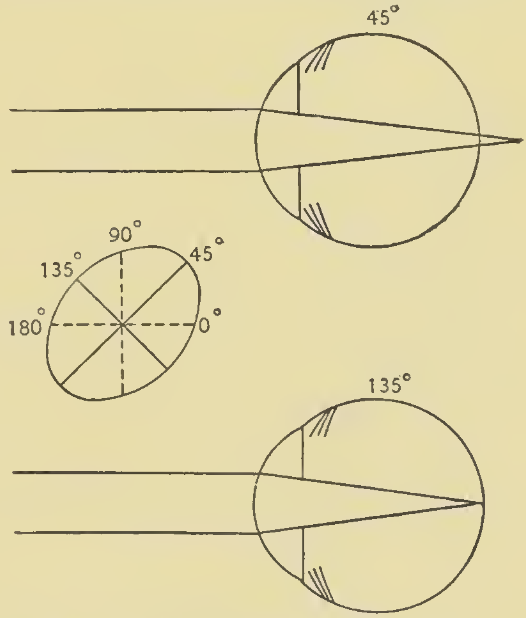


Fig. 28. — Astigmatism against the rule, with the axes at 45° and 135° (left eye).

+ .50 D. cyl., 180°, right eye ;

+ .50 D. cyl., 135°, left eye.

One year later, April, 1897, the glasses were still entirely satisfactory.

CASE XV. *Ophthalmometer shows no corneal astigmatism; Patient accepts a + .25 D. cylindrical glass against the rule, axis* 180° *in each eye.* — Mary T., aged forty, came to the clinic March 10, 1895, for glasses for reading and sewing. The patient is in good health.

Ophthalmometer. — No corneal astigmatism whatever, the lines dividing the mires being straight with each other in all meridians, and the images neither overlapping nor separating after once being approximated.

Retinoscopy was unsatisfactory, both as to the axis and the amount of the astigmatism, and even as to the kind.

Test cards and trial lenses. —

$$\text{R. V.} = \tfrac{20}{30} : \tfrac{20}{20} \quad \text{W.} + .25 \text{ D. cyl., } 180°.$$

$$\text{L. V.} = \tfrac{20}{40} : \tfrac{20}{20} - \text{W.} + .25 \text{ D. cyl., } 180°.$$

Reads Jaeger No. 1 at 10 inches with a + 1 D. spherical glass added.

Ophthalmoscope. — Emmetropic in each eye, apparently. The patient has a lachrymal catarrh, for which she was treated for three weeks before a second test was made.

Second test: The ophthalmometer gave the same reading and the patient accepted the same glass as on the first test. Ordered: + 1 D.s + .25 D. cyl., 180° for each eye for reading.

CASE XVI. *Ophthalmometer shows no corneal astigmatism: The patient accepts + .75 D. cylindrical glass against the rule, axis* 180° *in each eye.* — R. H. U., aged twenty-one, student, consulted me September 5, 1893. The patient is in good health, but somewhat run down from hard study. He complains of pain in the eyes, blurring of vision after long work, and also of a slight discharge from, and stiffness of, the lids.

Ophthalmometer. — No corneal astigmatism.

Retinoscope. — .50 D. astigmatism against the rule, with the chief axes at 180° and 90°?

Test cards and trial lenses. —

R. V. = $\frac{20}{20}$ – : $\frac{20}{20}$ + W. + .50 D. cyl., 180°.

L. V. = $\frac{20}{20}$ – : $\frac{20}{20}$ + W. + .50 D. cyl., 180°.

Reads Jaeger No. 1 at 5 inches.

A mild astringent wash was prescribed for the conjunctivitis. One week later a second test was made, the ophthalmometer still read negative, but the patient accepted + .75 D. cylindrical glass, axis 180°, over each eye, which was ordered. Three years later these glasses were still satisfactory, but at times the patient was troubled with conjunctivitis and a slight discharge from the lids.

Case XVII. *No corneal and no lenticular astigmatism, a moderate amount of latent hypermetropia.* — Miss R. G. L., aged twenty-three, consulted me October 24, 1896. She is in good health, but overworked in a "School of Applied Design," where she is trying to take a two years' course in one year's time, and as a consequence has overtaxed her eyes with fine drawing. For the past two weeks the left eye especially has pained her after working all day.

Ophthalmometer. — No corneal astigmatism whatever.

Test cards and trial lenses. —

R. V. = $\frac{20}{15}$: not improved with any glass.

L. V. = $\frac{20}{15}$: not improved with any glass.

Reads Jaeger No. 1 from $3\frac{1}{2}$ to 20 inches.

Ophthalmoscope. — Hypermetropia 1.25 D. both.

No muscular insufficiencies present.

This patient was ordered to discontinue some of her work, was put on tonics, and in a few weeks' time had no further trouble.

Contrary to the above case (that is, no corneal astigma-

tism), we usually have .50 D. of lenticular astigmatism against the rule when there is no corneal astigmatism present.

CASE XVIII. *Astigmatism with the rule, .25 D., axis 90° + or 180° –, according to the ophthalmometer; Patient accepts a + .25 D. cylindrical glass, axis 180°, against the rule.* — Annie D., aged twenty-seven, in good health. She came to the clinic at the Manhattan Eye and Ear Hospital on account of her eyes hurting when she did close work.

Ophthalmometer. — Astigmatism with the rule, .25 D., axis 90° + or 180° – in each eye.

Test cards and trial lenses. —

$$\text{R. V.} = \tfrac{20}{20} : \tfrac{20}{15} \text{ W.} + .25 \text{ D. cyl., } 180°.$$

$$\text{L. V.} = \tfrac{20}{20} : \tfrac{20}{15} \text{ W.} + .25 \text{ D. cyl., } 180°.$$

Reads Jaeger No. 1 at 6 inches.

The test with the lines on the clock-dial was unsatisfactory, as was also retinoscopy.

Ophthalmometer. — Hypermetropia .50 D. each eye.

A second test two days later gave the same result, and + .25 D. cylindrical glass, axis 180°, was ordered for each eye. These glasses have given satisfaction for over a year.

A second case similar to the above, that is, the patient accepting + .25 D. cylindrical glass against the rule (180°) when the ophthalmometer reads astigmatism with the rule .25 D., is furnished me by Dr. Van Fleet from his private practice; and I take this opportunity to express my thanks to him. I give the case as he reported it, with his remarks.

CASE XIX. *Corneal astigmatism with the rule, .25 D.; Patient accepts + .25 cylindrical glass against the rule and is relieved of a marked asthenopia, with marked improvement in vision.* — "Miss P., aged nineteen years, has suffered for some time with headache, dizziness, occasional diplopia, and attacks of momentary blindness. In November, 1896, while looking out

of a window at a passing parade everything suddenly appeared black to her, and she called to her sister who was in the room with her that she could not see. She felt sick and faint, and her family became alarmed and sent for the family physician, who responded at once, but by the time he arrived the attack had passed away.

"The physician, fearing some kidney trouble, examined his patient very carefully, but was unable to discover anything abnormal about her. During the two weeks he observed her she had several of these attacks, and finally concluding her eyes must be at fault, he referred her to me for examination.

"December 2, 1896. Patient is a large, healthy looking young woman, giving history as above.

"Pupils normal and react properly. No apparent deviation of visual lines.

"*Ophthalmometer.* — 0.25 D. with the rule.

"Ophthalmoscope, about emmetropic.

"Vision, both eyes $\frac{20}{40}$: $\frac{20}{20}$ – with + 0.25 D. cyl. ax. 180°.

"Reads J. 1 with and without this glass and has good range of accommodation.

"Ordered : + 0.25 D. cyl. ax. 180° constant.

"April 1, 1897. Physician reports that the patient is entirely free from all the asthenopic symptoms she formerly had.

"*Remarks.* — The history is peculiar for two reasons : first, it is unusual for such marked symptoms to result from so small a refractive error ; and second, it is unusual to have so great a diminution in vision made perfect with so weak a plus glass.

"It exemplifies also the value of Javal ophthalmometer and the almost constant relation between the amounts of corneal and lenticular astigmatism.

"One half diopter of corneal astigmatism with the rule being normal necessitates the existence of one half diopter of lenticular astigmatism against the rule.

"The existence of one diopter with the rule in the cornea

indicates an excess of one half diopter which must be corrected. Obversely, a total absence of corneal astigmatism leaves uncorrected one half diopter lenticular astigmatism, necessitating a glass of one half diopter against the rule.

"Therefore a quarter diopter of corneal astigmatism with the rule will correct one-half the normal lenticular astigmatism, necessitating one quarter diopter against the rule for complete correction."

The chief thing of interest in these last two cases, from the point of view of the ophthalmometer, is that the patients should wear a .25 D. cylindrical glass *against the rule* when the instruments reads .25 D. astigmatism *with the rule.* Its explanation is easy, if we only keep in mind the rule to deduct .50 D. from the reading of the instrument when the astigmatism is with the rule. In the above cases there is only .25 D. of corneal astigmatism, consequently if the lenticular astigmatism is of the usual amount (.50 D.), it will not only neutralize the .25 D. of corneal astigmatism, but leave .25 D. of its own, or lenticular, astigmatism to be corrected. But why does this remaining .25 D. of lenticular astigmatism require the cylindrical glass to be worn against the rule? This can be explained better by diagrams than in any other way. *A*, Fig. 29, shows the cornea, front view, and the points where the rays of light passing through its two chief meridians would focus if no lenticular astigmatism was present; *B* shows the lens, front view, and where the rays of light would focus after passing through its two chief meridians if no corneal astigmatism was present; and *C* represents a composite of the two as they actually are and the points where rays of light focus after passing through the two chief meridians of each.

The horizontal meridians of both the cornea and the lens in the above cases are emmetropic, as seen by the diagrams, and allow the rays of light to focus on the retina. The vertical meridian of the cornea is more curved by .25 D. than its

horizontal meridian. This is demonstrated by the overlapping of the images of the mires to the extent of .25 D. when they are turned from the horizontal to the vertical meridian after having been approximated. But the vertical meridian of the lens is too little curved by .50 D. It therefore neutralizes the .25 D. of corneal astigmatism (which is with the rule) and leaves still .25 D. lenticular astigmatism against the rule in the vertical meridian to be corrected, which requires + .25 D. cylindrical glass axis 180°.

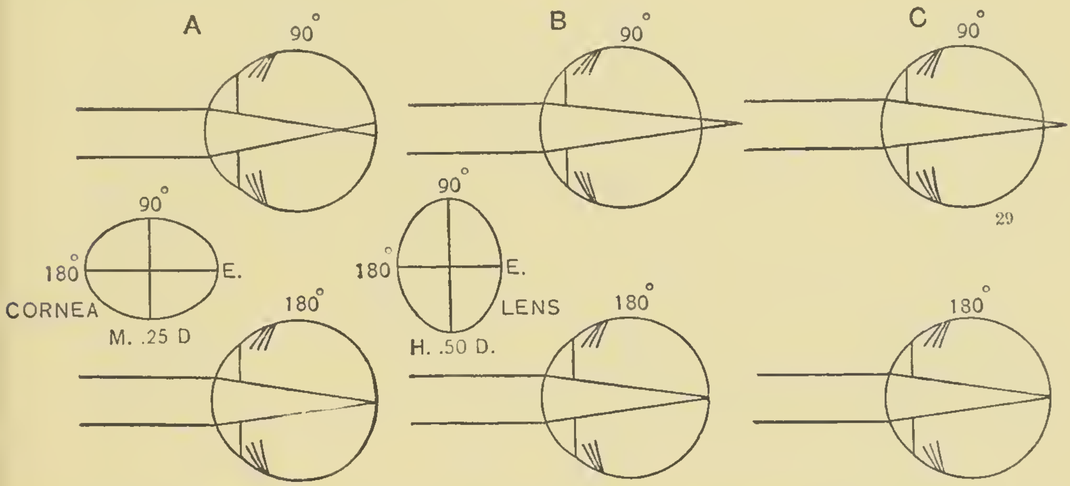


FIG. 29. — *A* shows the focuses of the two chief meridians of the cornea, assuming no lenticular astigmatism; *B*, the focuses of the two chief meridians of the lens, assuming no corneal astigmatism; *C*, the focuses of their combined action, with .25 D. corneal astigmatism with the rule and .50 D. of lenticular astigmatism against the rule.

Cases showing the variation of axes of the chief meridians of curvature of the cornea from 90° *and* 180°. — The plurality of cases of astigmatism have their chief meridians exactly at 90° and 180°, and, as a rule, the meridian that has a shorter radius of curvature is at 90°, while the meridian that has the longer radius of curvature is at 180°. Many times the two chief meridians are not exactly at 90°, but vary; and this variation in the majority of cases is symmetrical in character.[1] That is,

[1] Clairborne, *N. Y. Med. Jour.* June 25, and July 2. 1892. See also reference on page 200.

in cases of astigmatism with the rule, the shorter curved meridians slant the same number of degrees to the temporal, or nasal, side of 90° in each eye, while the longer curved meridians remain at right angles to the shorter curved meridians. For example, if the shorter curved meridian in the right eye is at 75°, that is 15° to the nasal side of 90°, the shorter curved meridian in the left eye is at 105°, or also 15° to the nasal side of 90°. In other words, both axes slant inward to the extent of 15° (see Fig. 30).

Fig. 30.

On the contrary, usually, if the shorter curved meridian in the right eye slants toward the temple 30°, the shorter meridian in the left eye slants toward the temple 30°. In such a case, the axis in the right eye would be at 120° and in the left eye at 60°, with the longer curved meridians respectively at right angles (see Fig. 31). In such a case, if the patient was hypermetropic, plus cylinders would be worn at 120° and 60°; if myopic, minus cylinders at 30° and 150°.

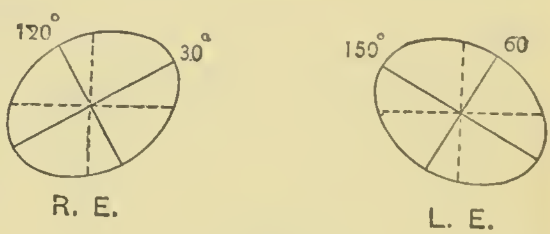


Fig. 31.

There are a number of exceptions to this rule, however. For instance, the meridian of shorter radius of curvature may slant but 10° to the temporal side of the vertical meridian in one eye and 15° to the temporal side in the other, etc. Or, again, the two chief meridians of curvature may be exactly at 90° and 180° in one eye, while the chief meridians may be slanting in the opposite eye; and so on.

At rare intervals, the shorter curved meridian in each eye may slant in the same direction from the vertical meridian, that

is, to the temple in one eye and to the nose in the other. For example, both of the shorter curved meridians may be at 75° (see Fig. 32).

In astigmatism against the rule the longer curved meridian is at 90° or its neighborhood, and is subject to the same variations as in the case of astigmatism with the rule.

Fig. 32.

In exceptional cases, the two chief meridians of curvature stand exactly at 45° and 135°. If this happens in both eyes, the meridian of the shorter radius of curvature is usually at 45° in one eye and at 135° in the other.

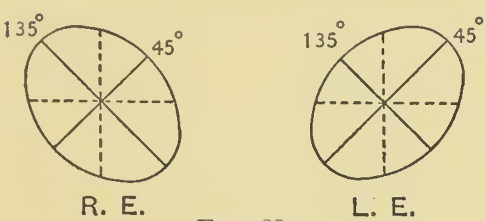


Fig. 33.

The symmetry of the eyes, as indicated in the beginning of this section, is thus carried out. For each shorter meridian in this instance would slant the same number of degrees from the vertical, and both either toward the temples, or both toward the nose (see Fig. 33).

In all of these cases, the ophthalmometer is of inestimable value in finding the axes, and no method compares with it for accuracy and facility.

Case XX. *Both axes slant* 30° *to the nasal side of the vertical meridian, standing at* 60° *in the right eye and at* 120° *in the left eye.* — Agnes R., aged twenty-seven, consulted me July 9, 1895. She had worn glasses for a year, but without relief of her eye symptoms, which were pain, blurring of vision, headaches, etc., in fact, typical asthenopia.

Ophthalmometer. — Astigmatism with the rule, 1 D., axis 60° + or 150° − right eye; 1 D., axis 120° + or 30° − left eye.

In the present case, in the right eye, the black lines dividing the mires were not straight at 0°, but were at 150°, and that

was the starting point or primary position. The mires were approximated, and the long indicator turned at right angles to the primary position or to 60°, where they overlapped one step. This was, therefore, astigmatism 1 D. with the rule, axis 60° + or 150° –.

In the left eye the primary position was found at 30°, and the secondary position at 120°.

Test cards and trial lenses.—

$$\text{R. V.} = \tfrac{20}{30} : \tfrac{20}{20} \text{ W.} + .50 \text{ D. cyl., } 60°.$$

$$\text{L. V.} = \tfrac{20}{20} : \tfrac{20}{15} \text{ W.} + .50 \text{ D. cyl., } 120°.$$

Reads Jaeger No. 1 at 6 inches.

Ophthalmoscope.—Hypermetropic astigmatism in each eye.

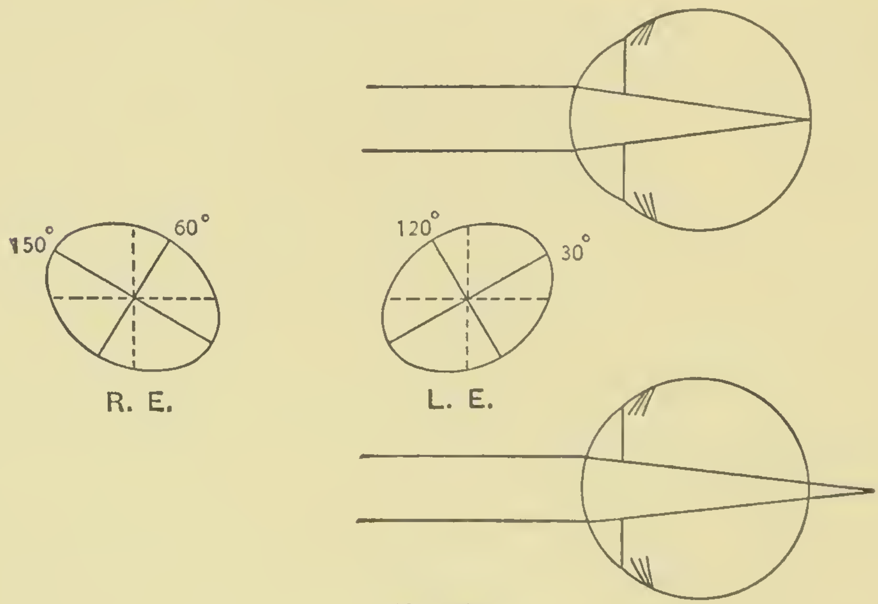


Fig. 34.

On the second test the patient accepted the same glass as at first. Ordered:—

+ .50 D. cyl., ax. .60° right;

+ .50 D. cyl., ax. 120° left.

Case XXI. *Both of the shorter axes slant* 15° *to the temporal side of the vertical meridian, standing at* 105° *in the right*

eye and at 75° *in the left eye.* — Hannah M., aged thirty, consulted me January 23, 1897. She complained that the eyelids became red and swollen at times, and of frontal headaches and pains in the eyeballs. Her general health is good.

Ophthalmometer. — Astigmatism with the rule, 1 D., 105° + or 15° – right eye; 1.50 D., 75° + or 165° – left eye.

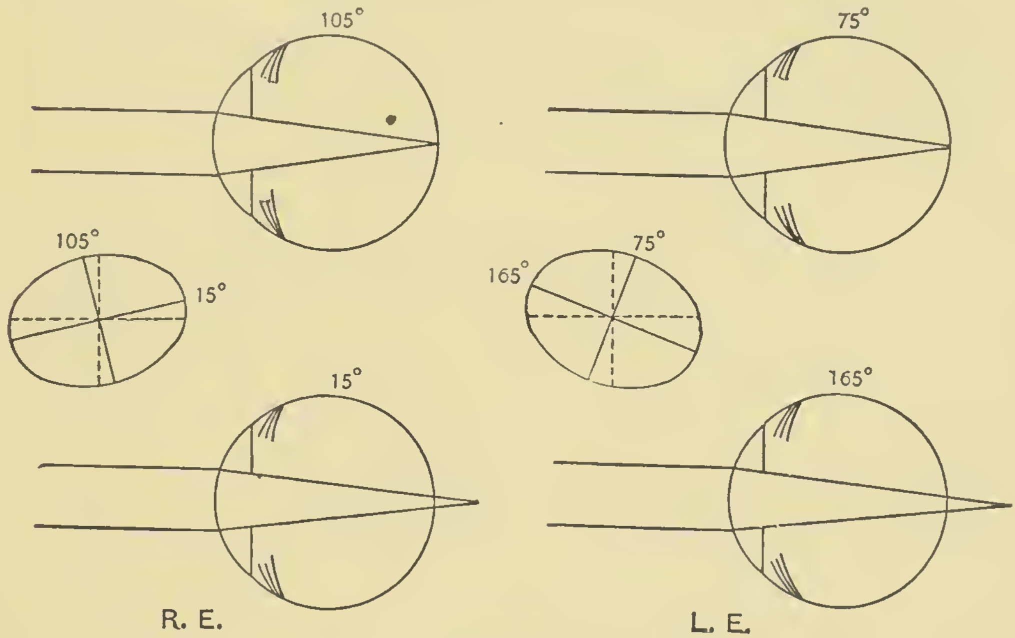


FIG. 35.

Test cards and trial lenses. —

R. V. $\frac{20}{30}$ – : $\frac{20}{20}$ W. + .50 D. cyl., 105°.

L. V. $\frac{20}{70}$ – : $\frac{20}{20}$ W. + 1 D. cyl., 75°.

Reads Jaeger No. 1 at 7 inches.

Ophthalmoscope. — Hypermetropic astigmatism with the rule.

A second test resulted the same as the first. Ordered : —

+ .50 D. cyl., 105° right eye ;

+ 1 D. cyl., 75° left eye.

Yellow oxide of mercury ointment was prescribed for the redness of the edges of the lids.

June, 1897. The patient has worn the glasses with perfect comfort, and the blepharitis marginalis has been relieved.

CASE XXII. *Both axes slant but 5° to the temporal side of the vertical meridian, standing at 95° in the right eye and at 85° in the left eye.*— Miss F. J. O., aged twenty, consulted me March 27, 1897. For two years she has been troubled by shadows whirling around in front of her eyes. These shadows are not constant, but appear at intervals and are annoying to the patient. She has no headache and no pain in the eyes.

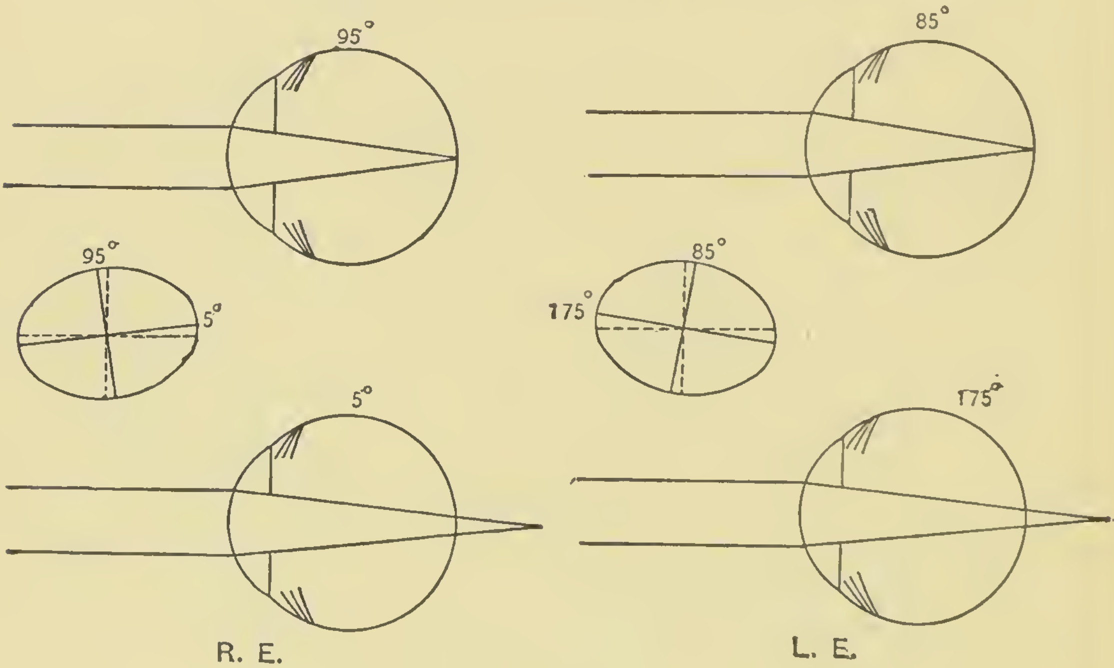


FIG. 36.

Ophthalmometer.— Astigmatism with the rule, 1.50 D., axis 95° + or 5° – right eye; 1 D., axis 85° + or 175° – left eye.

The primary position was found at 5° and the secondary at 95° in the right eye. The primary position was found at 175° and the secondary at 85° in the left eye.

It will be noticed that in most cases of astigmatism with "off" axes, that is, with the axes away from 90° and 180°, the secondary position can be obtained by adding 90° to the primary position when that is less than 90°, and by subtracting 90° from

the primary position when it is less than 90°. For instance, in this case the primary position in the right eye is at 5°, add 90° to it, and we get 95°, the secondary position. In the left eye the primary position is at 175°, subtract 90° from it, and we get 85°, the secondary position. This is true in all cases when the chief meridians are at right angles to each other, and they usually are.

Test cards and trial lenses. —

R. V. = $\frac{20}{40}$ – : $\frac{20}{20}$ W. + 1 D. cyl., 95°.
L. V. = $\frac{20}{40}$ – : $\frac{20}{20}$ W. + 1 D. cyl., 85°.

Reads Jaeger No. 1 at 4 inches.

Ophthalmoscope. — Simple hypermetropic astigmatism with the rule.

March 30, three days later, the ophthalmometer reads the same: —

R. V. = $\frac{20}{40}$ – : $\frac{20}{20}$ W. + 1 D. cyl., 95°.
L. V. = $\frac{20}{40}$ – : $\frac{20}{20}$ W. + .75 D. cyl., 85°.

Ordered: —

+ 1 D. cyl., 95° right;
+ .75 D. cyl., 85° left.

Two months later the glasses were satisfactory.

CASE XXIII. *Axis vertical or* 90° *in one eye, and* 15° *from the vertical in the other eye, standing at* 75°. — Robert I., aged fifteen, consulted me October 12, 1895. He suffered from a typical asthenopia and a mild conjunctivitis. He is in good general health, but a close student.

Ophthalmometer. — Astigmatism with the rule 1 D., axis 75° + or 165° – right eye; 2.50 D., axis 90° + or 180° – left eye.

The primary position in the right eye was found at 165° and the secondary at 75°. The primary position in the left eye was found at 0° or 180° and the secondary at 90°.

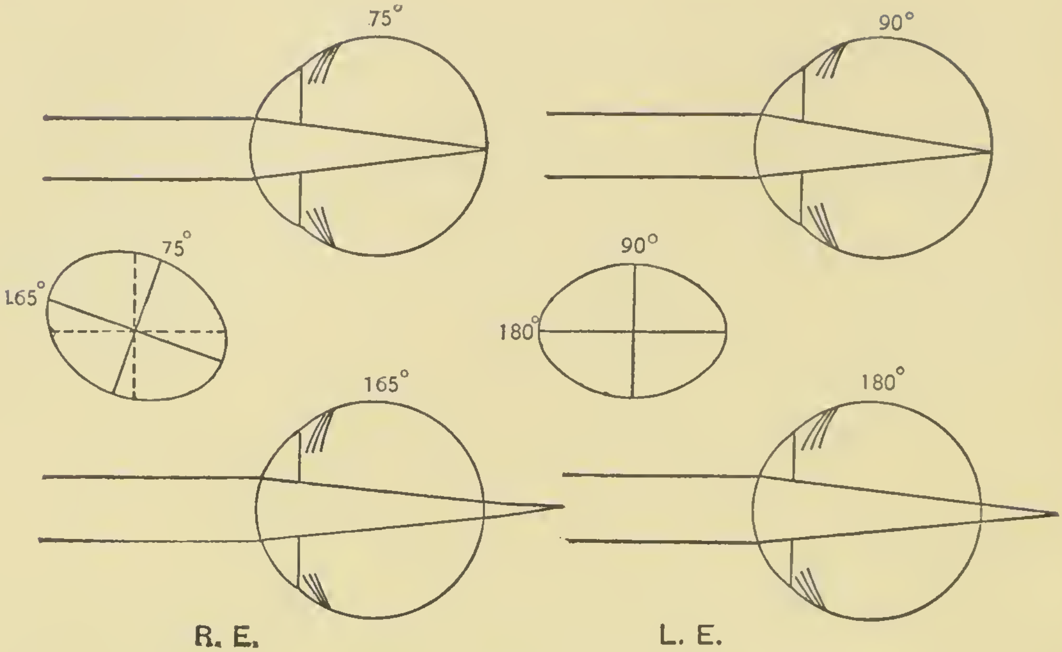


Fig. 37.

Test cards and trial lenses. —

R. V. = $\frac{20}{40}$ — : $\frac{20}{20}$ W. + .75 D., cyl., 75°.

L. V. = $\frac{20}{70}$ — : $\frac{20}{20}$ W. + 2 D., cyl., 90°.

Reads Jaeger No. 1 at 5 inches.

Ophthalmoscope. — Simple hypermetropic astigmatism with the rule in each eye.

A mild astringent wash was ordered for the conjunctivitis, and the above glasses ordered: —

+ .75 D., cyl., 75° right;

+ 2 D., cyl., 90° left.

May 1, 1896, the glasses were still satisfactory.

Case XXIV. *Both axes slant* 15° *in the same direction from the vertical meridian, to the temporal side in the right and to the nasal side in the left, standing in each at* 105°. — R. E. P., aged thirty-seven, consulted me November 8, 1896, complaining of frontal headaches and pains in the eyes after reading or

working. His general health is not very good, is a business man and overworked.

Ophthalmometer. — Astigmatism with the rule 1 D., axis 105° + or 15° – in each eye. The primary position in each instance was found at 15° and the secondary at 105°.

Test cards and trial lenses. —

$$\text{R. V.} = \tfrac{20}{20} - : \tfrac{20}{15} \text{ W.} + .50 \text{ D. cyl., } 105°.$$
$$\text{L. V.} = \tfrac{20}{20} - : \tfrac{20}{15} \text{ W.} + .50 \text{ D. cyl., } 105°.$$

Reads Jaeger No. 1 at 7 inches.

Ophthalmoscope.—Simple hypermetropic astigmatism in each eye.

On a second test the patient accepted the same glasses as at first. Ordered: + .50 D. cyl., 105°, each eye. These glasses have continued to give comfort for six months, May 2, 1897, when the patient was last heard from.

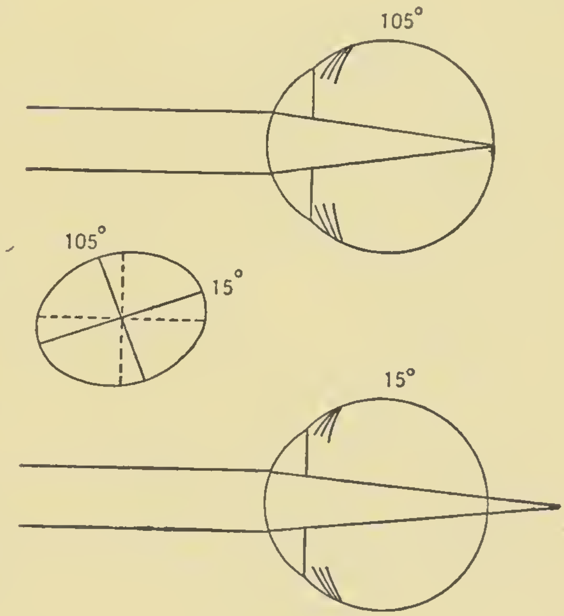


Fig. 38.

Case XXV. *Astigmatism against the rule where the axes of the glasses slant relatively the same number of degrees from the horizontal meridian, standing at* 15° *in one eye and at* 165° *in the other eye.* — In hypermetropic astigmatism against the rule and myopic astigmatism with the rule, when the axes vary from 90° and 180°, they usually slant the same number of degrees and relatively in the same direction from the horizontal meridian. However, there are exceptions just as numerous as the variations noted in the cases of hypermetropic astigmatism with the

rule, above reported, and myopic astigmatism against the rule, to be reported, in regard to the vertical meridian.

Mrs. N. E. R., aged thirty-nine, consulted me March 2, 1897. She had worn glasses for a year, but her eyes continued to pain her when she did any near work. Frontal headaches, dizziness, and a drawing sensation in the eyes are the symptoms most complained of.

Ophthalmometer. — Astigmatism against the rule, .50 D., axis 15° + or 105° – right eye; .25 D., axis 165° + or 75° – left eye.

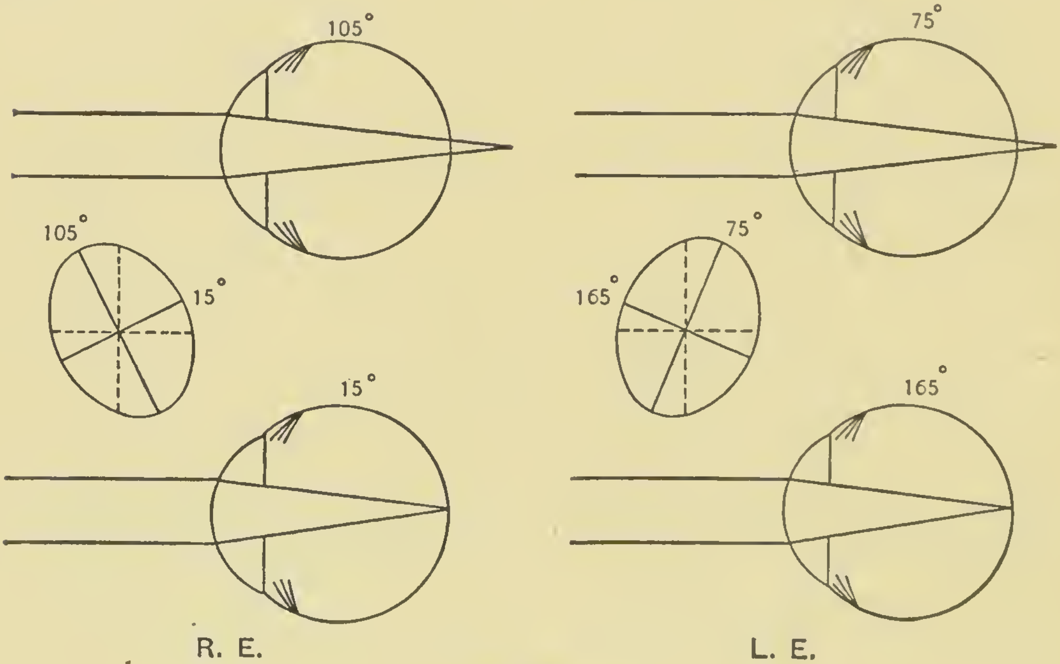


FIG. 39.

The primary position in the right eye was found at 15°, the images of the mires approximated and the long indicator turned to 105° when the images separated: the images were again approximated and the long indicator turned back to 15°, the primary position, when an overlapping of one-half a step took place. In astigmatism against the rule it is after this second turning that the axes and the amount of astigmatism are read off, the long indicator always showing where the plus glass will be worn if hypermetropia is present and the

short indicators where the minus glass will be worn if myopia is present.

In the left eye the primary position was found at 165°, the secondary at 75° where the images separated. The images were again approximated and turned back to the primary position, when an overlapping of a quarter of a step took place, reading, therefore, astigmatism against the rule, .25 D., axis 165° + or 75° −.

Test cards and trial lenses. —

R. V. = $\frac{20}{30}$ − : $\frac{20}{20}$ + W. + 1 D. cyl., 15°.

L. V. = $\frac{20}{20}$ − : $\frac{20}{20}$ + W. + .50 D. cyl., 165°.

Reads Jaeger No. 1 at 8 inches.

Ophthalmoscope. — Simple hypermetropic astigmatism against the rule each eye. Ordered : —

+ 1 D. cyl., 15° right eye ;

+ .50 D. cyl., 165° left eye.

CASE XXVI. *Astigmatism with axes at* 45° *and* 135°. — Annie D., aged 14, was examined by me at the clinic July 10, 1894. She was in good health, but suffered constantly from her eyes, more when she used them for close work. In fact, it was a typical case of asthenopia.

Ophthalmometer. — Astigmatism with the rule, 2 D., axis 45° + or 135° − right eye ; astigmatism against the rule, 2 D., axis 135° + or 45° − left eye.

Perhaps it is well here again to refer to the fact that when the two chief meridians of curvature fall exactly at 45° and 135°, just halfway between the vertical and horizontal meridians, that, strictly speaking, we do not have astigmatism with or against the rule. But for the sake of uniformity of reading of

the instrument we speak of these cases as being with and against the rule, just as in other cases.

Furthermore, to make the reading of the instrument uniform, we have assumed one or the other of the meridians, either 45° or 135°, always as the primary position or starting point. For myself I always take 135° as the primary position in such cases. Starting with 135° as the primary position and turning the long indicator to 45°, that is at right angles, if the mires over-

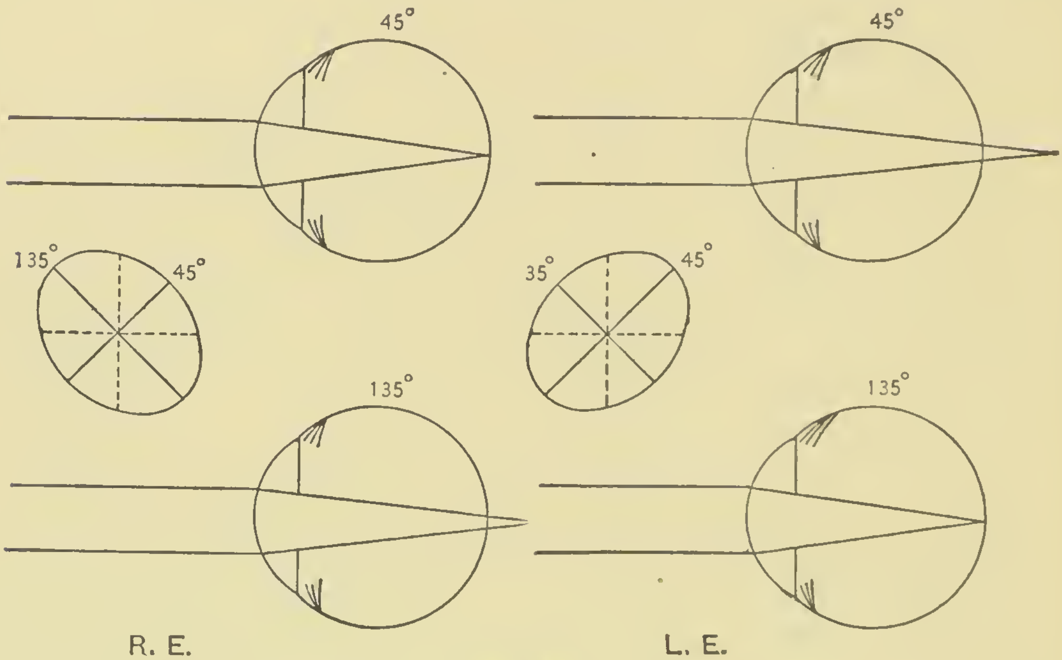


Fig. 40.

lap we call the astigmatism with the rule, just as at other times when the mires overlap; and if the mires separate when we reach 45° we call it astigmatism against the rule, approximate the mires a second time, and turn back to the primary position at 135° to get the amount of overlapping.

It must be remembered, too, in these cases with the axes at 45° and 135°, that the subtraction of .50 D. from the reading of the instrument when the astigmatism is with the rule and the addition of .50 D. to the reading when it is against the rule does not always hold.

In the present case in the right eye the lines dividing the mires became straight with each other at 135° (primary position); the images of the mires were then approximated and turned to 45° (secondary position), when two steps of overlapping took place; astigmatism with the rule, 2 D., axis 45° + or 135° –. In the left eye the primary position was also found at 135°, the images of the mires approximated, and the long indicator turned to 45° (second position), when the images of the mires separated. The images were again approximated, and the long indicator turned back to the primary position at 135°, when they overlapped two steps; astigmatism against the rule, 2 D., axis 135° + or 45° –.

Test cards and trial lenses. —

R. V. = $\frac{20}{50}$: $\frac{20}{30}$ W. + 1.50 D. cyl., 45°.

L. V. = $\frac{20}{50}$: $\frac{20}{30}$ W. + 2 D. cyl., 135°.

Reads Jaeger No. 1 at 5 inches.

Ophthalmoscope. — Simple hypermetropic astigmatism.

July 8, second test was given and the patient accepted the same glass. Ordered : —

+ 1.50 D. cyl., 45° right eye ;
+ 2 D. cyl., 135° left eye.

The lines on Green's clock-dial from I to VII and from II to VIII were seen plainest with the right eye ; and the lines from X to IV and from XI to V in the left eye.

The reason that the patient saw two sets of lines plainly in each eye is that there are no lines on Green's dial corresponding exactly to 45° and 135°. The lines on the clock-dial correspond to 0° or 180°, 30°, 60°, 90°, 120°, and 150°. As a consequence there are two sets of lines equidistant on either side of 45°, and two sets equidistant on either side of 135°, seen equally plainly when the axes happen to be exactly at 45° and 135°. A glance at the clock-dial will quickly show how this is. Perhaps a better

set of lines are those of Snellen, fan-shaped, which are much closer together than those on Green's clock-dial, corresponding at least to every fifteen degrees.

I may say here by way of explanation of the principle of Green's clock-dial arrangement of lines, that when the horizontal lines are seen plainest, assuming no spasm of accommodation to be present, the presence of one of six conditions of error of refraction is indicated: (1) a simple hypermetropic astigmatism, (2) a compound hypermetropic astigmatism, (3) a mixed astigmatism with the hypermetropic portion greater than the myopic portion, all with the rule; or (4) a simple myopic astigmatism, (5) a compound myopic astigmatism, (6) a mixed astigmatism with the myopic portion greater than the hypermetropic portion, all against the rule. A glance at Figs. 9, 10, 13, 16, 17, 18, in Chapter II, will show this, the lines that are seen plainest always corresponding with the meridian of greatest error of refraction.

The horizontal meridian in all of the above cases is the one most at error, while the vertical is emmetropic or more nearly so than the horizontal in all of them. As the horizontal lines on the clock-dial are seen by means of the rays of light that pass through the vertical meridian of the cornea, it follows as a consequence that the horizontal lines on the dial will be seen plainest in the above cases. This is based on a simple principle of optics. We see lines by means of rays of light that light them up from side to side (a, a', Fig. 41), and not by the rays of light that strike them in their horizontal or longitudinal direction (b, b', Fig. 41).

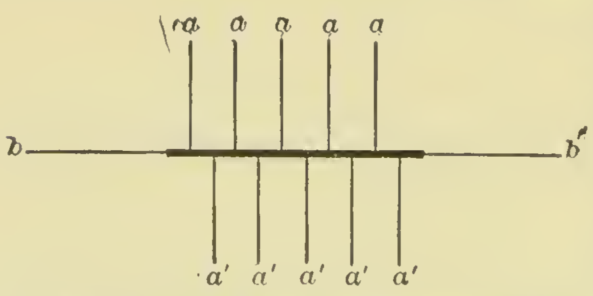


FIG. 41. — Showing how lines are seen by rays of light that strike them from side to side, a, a', and not by rays that strike them at their ends, b, b'.

On the other hand, had the vertical lines been seen plainest, this would have indicated one of six other conditions, to wit: (1) Simple myopic astigmatism, (2) compound myopic astigmatism, (3) mixed astigmatism with the myopic portion greater than the hypermetropic, all with the rule; or (4) simple hypermetropic astigmatism, (5) compound hypermetropic astigmatism, (6) mixed astigmatism with the hypermetropic portion greater than the myopic portion, all against the rule.

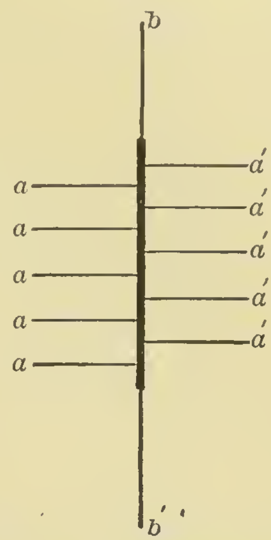


FIG. 42. — Showing how vertical lines are seen by rays of light, a, a', that strike them from side to side.

The horizontal meridian is emmetropic or more nearly so than the vertical in all six conditions. Therefore the vertical lines on the clock-dial will be seen plainest (Fig. 42).

CHAPTER IV

COMPOUND HYPERMETROPIC ASTIGMATISM — ILLUSTRATIVE CASES — SPASM OF ACCOMMODATION

In compound hypermetropic astigmatism the ophthalmometer is used in exactly the same way as in simple hypermetropic astigmatism ; or, for that matter, as in every form of astigmatism, that is, to find the position of the two principal meridians of curvature of the cornea and the amount of the astigmatism. These points once obtained, the character of the error of refraction, if hypermetropic or myopic, is, in the great majority of cases, easily found out with the aid of the trial case, aided by the ophthalmoscope and other objective tests. In exceptional cases a mydriatic has to be called into requisition before a satisfactory glass can be prescribed, but such cases are very rare, as shown in the preceding chapter.

Here again I wish to emphasize the importance of correcting the astigmatism first ; for if there happens to be only a simple astigmatism present, we have gone to the root of the trouble at once ; and if a spherical error is present in addition to the astigmatism, we have disposed of the astigmatism and have only the spherical error left to deal with, as in simple hypermetropia and myopia. This method of procedure is of great advantage when there is a tendency to spasm of accommodation : for, after the astigmatism has been corrected in each eye separately, we can then put spherical glasses before both eyes at once. In this way, as is well known, the tendency to spasm of accommodation is overcome, and the patient many times accepts stronger plus, or weaker minus, glasses than when one

eye is tested at a time. However, it should not be forgotten that spherical glasses should be tried in addition to the cylindrical glasses on each eye separately, before both eyes are tried together, for there may be more spherical error in one eye than the other. For example, say the patient accepts in the right eye + 1 D. + 2 D. cyl., 90°, and in the left eye + .50 D. + 2 D. cyl., 90°, when each eye is tested separately. If we suspect spasm of accommodation, we should leave the cylindrical glasses as they are and place in front of them at the same time a + .25 D. stronger spherical glass than they accepted singly. In this instance, in front of the right eye + 1.25 D. and in front of the left + .75 D. If these are accepted, add + .25 D, stronger sphere yet, and continue till the vision begins to be made worse. Where the patient does not accept as strong a cylindrical glass as indicated by the ophthalmometer, I often try both eyes at the same time with cylindrical glasses. Of course, this is after the eyes have been tried separately, when both cylindrical glasses can be increased proportionately in strength, just as in the case of spherical glasses.

In compound hypermetropic astigmatism, spasm of accommodation is more often present perhaps than in any other form of error of refraction. I have already shown in Chapter III, page 42 *et sequiter*, how it may be avoided if the test is begun and conducted properly. In the latter part of this chapter I treat of it in detail, — its causes, signs of its presence, and how to overcome it in most cases without the unnecessary use of mydriatics, together with illustrative cases. In this way I hope to show that this bugbear of refraction is not so much to be dreaded after all, and that a mydriatic is not the only weapon it can be fought with, though occasionally it has to be called into requisition as a last resort.

I am not among those who believe in the use of the milder mydriatics, such as homatropine, because I believe when a mydriatic is needed, it is needed, and I use an efficient one

when I do use one, which is seldom. The two that I rely upon are atropine and scopolamine. The atropine is used in 4 grains to ℥i solution for adults and half that strength for children, one drop being instilled into each eye three times a day for three days, after which the test is made. Then a week is allowed to elapse for the effects to wear off, when another test is made, and usually the glass that the patient accepts on this last test is given. For, while it will not be so strong a glass as the patient accepted under the atropine, yet it will be stronger than the glass that was accepted before the mydriatic was instilled, because the week's enforced rest under the mydriatic has left the eye quiet and relieved the spasm of accommodation. However, should the glasses accepted on this last test not be strong enough, as compared by the glasses accepted while under the influence of the mydriatic, a large amount of latent hypermetropia being present, I correct part of this latent hypermetropia (one-half to two-thirds of it) in addition to the manifest hypermetropia.

Patients when given atropine to take home with them to be instilled into the eyes should be cautioned as to its poisonous effects at times, especially in children. Any flushing of the face or dryness of the throat should be the sign to stop its use.

Scopolamine hydrobromid, 1 gr. to ℥i solution for adults and half that strength for children, is a very efficient and quick mydriatic. It is to be instilled into the eye of the patient by the doctor in the office, one drop in each eye every five minutes for thirty minutes, having the patient press his fingers over the tear-sac at the inner canthus of each eye all the while, so that none of the solution goes into the nose. Then have the patient wait for thirty minutes (one hour in all) before the test is begun.

The advantages of scopolamine over atropine are: (1) that it is more powerful; (2) it acts quicker, getting the patient ready for testing in one hour's time; (3) its effects disappear

more rapidly, lasting only from two to five days, while the effects of atropine last a week to ten days. Some few cases of poisoning have been reported from its use in the eyes,[1] the toxic symptoms — rapidity of the pulse, flushing of the face, dryness of the throat, dizziness, at times nausea, and, in extreme cases, delirium — being alarming in some cases. In most of the cases of poisoning reported, either the precaution of pressing on the tear-sac was not observed or the drug was used too freely. Just as with atropine, some cases are much more susceptible to it than others, hence it should be used with caution. However, with proper precaution it can be used with safety.

Amblyopia, which is often present in high degrees of compound hypermetropic astigmatism, is often a stumbling-block for beginners, on account of which they often use a mydriatic when none is called for. In such cases, not being able to improve the vision much with any glass, they think perhaps it is their own fault in not fitting the glasses correctly that the patient does not obtain better vision, not stopping to consider that amblyopia may be present, and that no glass whatever will give better vision. They accordingly use a mydriatic, but find after all that the patient cannot be made to see any better with the glasses accepted under the use of a mydriatic than with those accepted at first. They have simply had their trouble for nothing besides giving the patient great inconvenience.

My own practice in such cases is to give two tests on different days. If the second test corresponds with the first, I order the glasses that are accepted though they do not improve the vision much. By the use of the ophthalmometer we know if any corneal astigmatism is present or not, and, if present, its axis and amount. With this important point ascertained we know approximately beforehand what cylindrical glass the

[1] Pooley, Foster, and Smith, among others, in this country, while several cases have been reported abroad.

patient should accept and do not have to depend so much on his answers. After the astigmatism is once corrected, the spherical part of the error is corrected with comparative ease. Of course, if the two tests do not agree, and if there is a question of spasm of accommodation, I do not hesitate to use a mydriatic, and a strong one. After a mydriatic has been employed, retinoscopy may be brought to the aid of the other tests. But without the use of a mydriatic I have not found retinoscopy satisfactory ; for that reason I rarely employ retinoscopy in my practice, since I use mydriatics so seldom.

Some illustrative cases will serve to bring out the points I have mentioned above.

CASE XXVII. *Ophthalmometer shows astigmatism with the rule*, 1 *D. ; Patient accepts compound plus glasses with relief of asthenopia and conjunctivitis.* — Sophia F., aged twenty-four, in good health, complains that she has frequent headaches, and that her eyes ache after using them, also that the eyelids itch and burn at times.

Ophthalmometer. — Astigmatism with the rule, 1 D., axis 90° + or 180° − in each eye.

Test cards and trial lenses. —

R. V. = $\frac{20}{30}$ − : $\frac{20}{20}$ W. + .50 D. + .50 D. cyl., 90°.

L. V. = $\frac{20}{30}$ − : $\frac{20}{20}$ W. + .50 D. + .50 D. cyl., 90°.

Reads Jaeger No. 1 at 6 inches.

Ophthalmoscope. — Hypermetropia in the vertical meridian 1.50 D., and in the horizonal meridian 2 D., in each eye respectively.

On account of a mild conjunctivitis, an astringent wash was ordered for the lids and the patient directed to return in two weeks.

Second test : the ophthalmometer reads the same as at the first test.

Test cards and trial lenses. —

R. V. = $\frac{20}{30}$: $\frac{20}{20}$ W. + 1 D. + .50 D. cyl., 90°.

L. V. = $\frac{20}{30}$: $\frac{20}{20}$ W. + 1 D. + .50 D. cyl., 90°.

The ophthalmoscope showed about the same condition as on the first test. The conjunctivitis is much improved. Ordered: +1 D. + .50 D. cyl., 90° each eye. These glasses have been worn for more than four years with relief from her asthenopic symptoms.

CASE XXVIII. *Large amount of astigmatism with the axis slanting relatively the same number of degrees from the vertical meridian, 15° to the nasal side, in each eye; Patient accepts a compound plus glass with relief of asthenopic symptoms.* — March 14, 1893, Mary D., aged twenty-four, in good health, but her eyes ache after she uses them for a short time for close work, especially in the evening.

Ophthalmometer. — Astigmatism with the rule, 3 D., axis 75° + or 165° – right eye; 3 D., axis 105° + or 15° – left eye.

FIG. 43.

Test cards and trial lenses. —

R. V. = $\frac{20}{70}$ – : $\frac{20}{40}$ W. + 3 D. + 2.50 D. cyl., 75°.

L. V. = $\frac{20}{70}$ – : $\frac{20}{40}$ W. + 3 D. + 2.50 D. cyl., 105°.

Reads Jaeger No. 1 at 6 inches.

Ophthalmoscope. — Hypermetropia 3.50 D. at 75° and 6.50 D. at 165° right eye; and 3.50 D. at 105° and 6.50 D. at 15° left eye.

The lines on the clock-dial from II to VIII were seen best with the right eye, and from X to IV in the left eye. The simple cylindrical glass before each eye served to bring out all the lines on the clock-dial equally clear, indicating that the astigmatism had been corrected. On a second test the patient accepted exactly the same glass as on the first test, and it was ordered, and has been worn with comfort ever since.

Case XXIX. *Astigmatism against the rule,* 1 *D., with the axis* 15° *from the horizontal meridian in each eye; Patient accepts compound plus glasses and gets relief from asthenopia.* — May 11, 1892, Mrs. C. W. T., aged thirty-nine, in good general health,

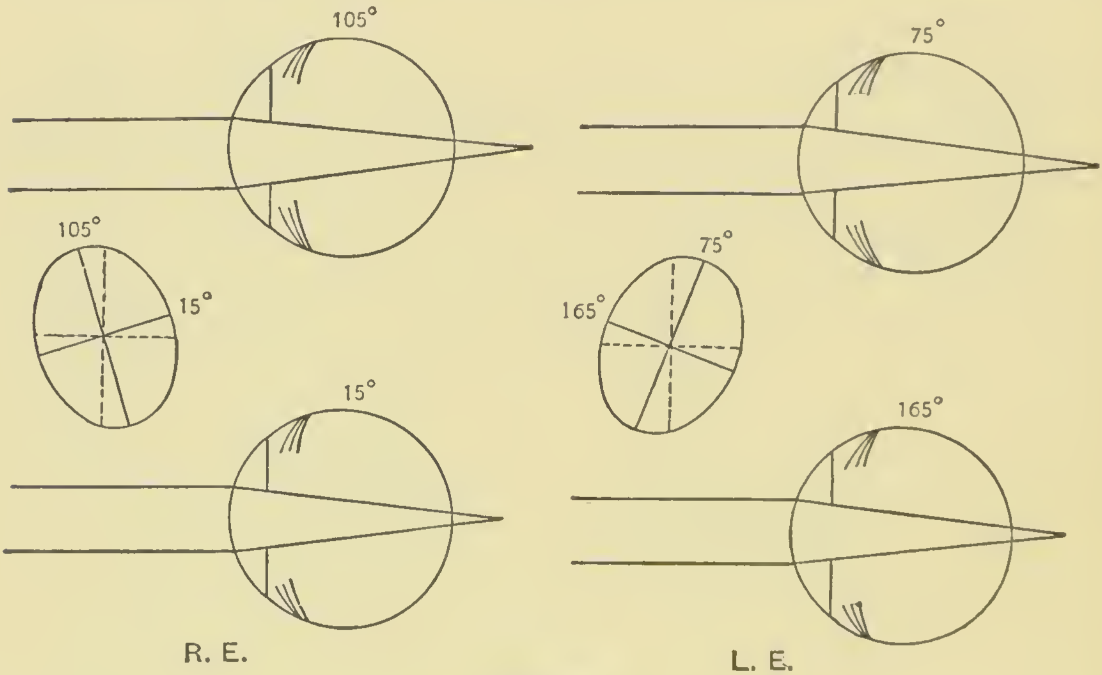


Fig. 44.

came for glasses on account of painful vision and headaches. The pupil in the left eye was dilated for some weeks when she was a child, from some unknown cause. She never had scarlet fever or diphtheria, or any serious illness.

Ophthalmometer. — Astigmatism against the rule, 1 D., axis 15° + or 105° − right eye; 1 D., axis 165° + or 75° − left eye.

Test cards and trial lenses. —

R. V. = $\frac{20}{30}$: $\frac{20}{15}$ W. + 1 D. + 1 D. cyl., 15°.

L. V. = $\frac{20}{30}$: $\frac{20}{15}$ W. + .75 D. + 1 D. cyl., 165°.

Reads Jaeger No. 1 at 8 inches.

Ophthalmoscope. — H. 2.50 D. at 105° and 1.50 D. at 15°, right eye; H. 2.50 D. at 75° and 1.50 D. at 165°, left eye.

On a second test, three days later, the patient accepted exactly the same glass in the left eye and a quarter diopter weaker spherical glass in the right. Ordered: —

+ .75 D. + 1 D. cyl., 15° right;

+ .75 D. + 1 D. cyl., 165° left.

These glasses have been worn for five years with comfort. However, as she is becoming presbyopic, she will soon have to wear stronger glasses for reading and close work.

Case XXX. *Small amount of astigmatism associated with a large amount of hypermetropia; Marked asthenopia; Relief with glasses.* — November 27, 1893, Miss M. H., aged thirty-five, in good health, came for glasses because her old glasses did not suit her. She has worn glasses for the last six years. The vision blurs after reading for a few moments, and she has to stop and rub the eyes before she can continue.

Ophthalmometer. — Astigmatism with the rule, 1.25 D., axis 90° + or 180° − right eye; 1.25 D., axis 105° + or 15° − left eye.

Test cards and trial lenses. —

R. V. = $\frac{20}{200}$: $\frac{20}{40}$ W. + 4 D. + .75 D. cyl., 90°.

R. L. = $\frac{20}{200}$: $\frac{20}{40}$ W. + 4 D. + .75 D. cyl., 105°.

Reads Jaeger No. 1 at $7\frac{1}{2}$ inches.

Ophthalmoscope. — H. 4 D. at 90° and 5 D. at 180° right eye; H. 4 D. at 105° and 5 D. at 15° left eye.

A second test resulted in the patient accepting exactly the same glass as at the first test, and it was ordered. They have been worn four years, with entire relief of asthenopic symptoms.

The point of interest in this case, as far as fitting the glasses is concerned, is the order of sequence in which the glasses should be placed in the trial frames during the test. That is, if cylindrical glasses should be tried first, or spherical

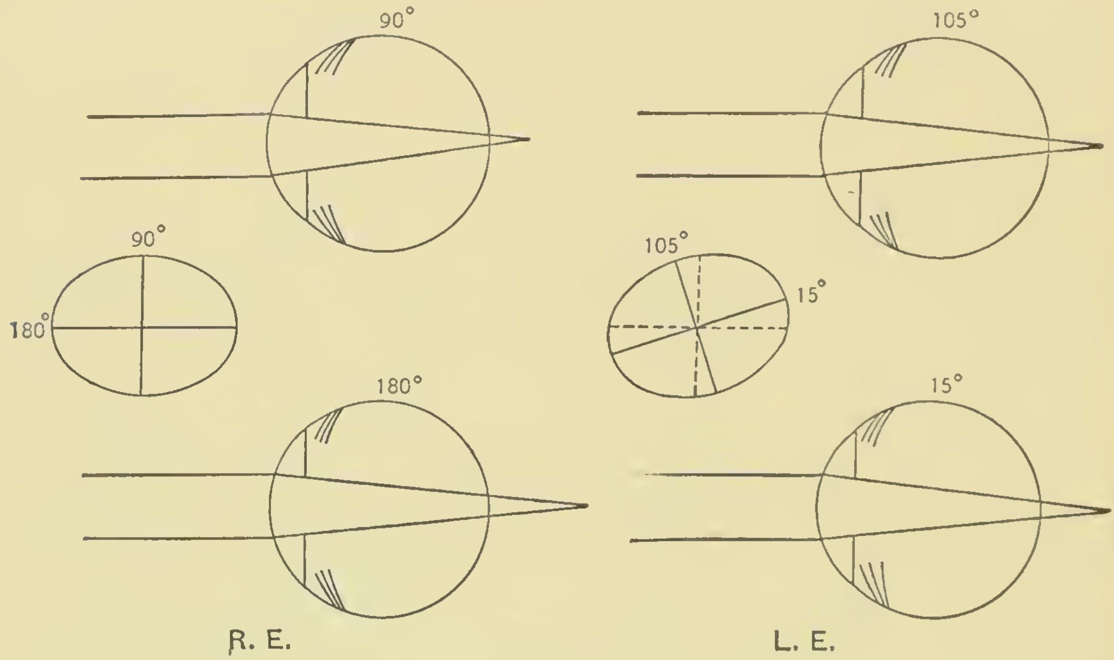


Fig. 45.

glasses. In an article on the *Technics of the Trial Case*,[1] I have stated it as a rule to be generally followed, that in cases of compound astigmatism it is always best to correct the astigmatism first, unless there is a large amount of spherical error present, — a hypermetropia of 6 D. or more, a myopia of 8 D. or more, with only a small amount of astigmatism present. Perhaps in that statement I gave the amount of the spherical error too large in cases where it is necessary first to correct part of the spherical error before correcting

[1] *New York Med. Jour.*, June 20, 1896.

the astigmatism; for I have sometimes found it necessary in cases of hypermetropia of only 4 D., and in myopia of only 6 D., with a small amount of astigmatism present, to correct part of the spherical error before the patient could appreciate the effect of a weak cylindrical glass when placed in front of the eye. In fact, in the present case, with 4 D. of hypermetropia and 1.25 D. of corneal astigmatism, part of the spherical error had to be corrected first before the cylindrical glasses could be appreciated. Usually, however, in cases of hypermetropia of 4 D. and less and myopia of 6 D. and less, complicated with an astigmatism of as much as 1 D., the cylindrical glass will be appreciated and vision improved to a slight extent with it alone, and before the spherical glass is added. The tendency in such cases, — large amount of spherical error associated with small amount of astigmatism, — where the cylindrical glasses are tried first, is for the patient to accept too strong cylindrical glasses. I am careful in such cases, at the close of the test, to weaken the cylindrical glasses slightly and at the same time to increase the strength of the spherical glasses a little, to see if the vision is improved by the change. If it is, I make the change; if not, I give the original glass as first accepted. I mention this fact here for the benefit of beginners and because it is a point of practical importance. I may say, on the other hand, for those who make it a habit to correct the spherical error first, that the reverse condition holds; that is, the patient is liable to accept too strong a spherical glass relative to the cylindrical glass. In such case it is well to weaken the spherical glass at the close of the test and at the same time increase the strength of the cylindrical glass to find if vision can be improved.

Again, in such cases as the one reported, the patient may accept the cylindrical glass as indicated by the ophthalmometer without either improving or making the vision worse. In such a case, leave the cylindrical glass on and proceed to cor-

rect the spherical error. When this is corrected, you will find that the vision is made worse if the cylindrical glass is removed, though while the cylindrical glass was on alone it seemed not to affect the vision one way or the other. This is easily accounted for. The spherical error being large, and the astigmatism being small, the cylindrical glass while on by itself has but little appreciable effect, but when the spherical error is corrected (if there is not a marked amblyopia present), the vision is brought up to something like the normal, and the eye can then appreciate the presence or absence even of a weak cylindrical glass, which it could not do at first.

CASE XXXI. *Hypermetropic astigmatism in each eye of equal amount, 2 D.; Patient accepts a simple plus cylindrical glass in one eye, and a compound plus glass in the other; Relief from asthenopia.* — May 9, 1893, Hannah D., aged twenty-five, has good general health, but has had weak eyes since a child. After any close work she has headaches and pains in the eyes, especially the left eye.

Ophthalmometer. — Astigmatism with the rule, 2 D., axis 75° + or 165° − right eye; 2 D., axis 120° + or 30° − left eye.

Test cards and trial lenses. —

$$\text{R. V.} = \tfrac{20}{70} - : \tfrac{20}{30} \text{ W.} + 1.75 \text{ D. cyl., } 75°.$$

$$\text{L. V.} = \tfrac{20}{70} - : \tfrac{20}{30} \text{ W.} + 1.50 \text{ D. cyl., } 120°.$$

Reads Jaeger No. 1 at $5\frac{1}{2}$ inches.

Ophthalmoscope. — H. 2 D. at 165° and emmetropia at 75° right eye; H. .50 D. at 120° and H. 2 D. at 30° left eye.

Two days later a second test was made. The ophthalmometer read exactly the same, both as to the axis and amount of the astigmatism in the left eye as at the first test; and the same axis, but .50 D. more in amount for the right eye.

Test cards and trial lenses. —

R. V. = $\frac{20}{70}$ — : $\frac{20}{20}$ W. + 2 D. cyl., 75°.

L. V. = $\frac{20}{70}$ — : $\frac{20}{20}$ W. + .50 D. + 1.50 D. cyl., 120°.

Reads Jaeger No. 1 at $5\frac{1}{2}$ inches.

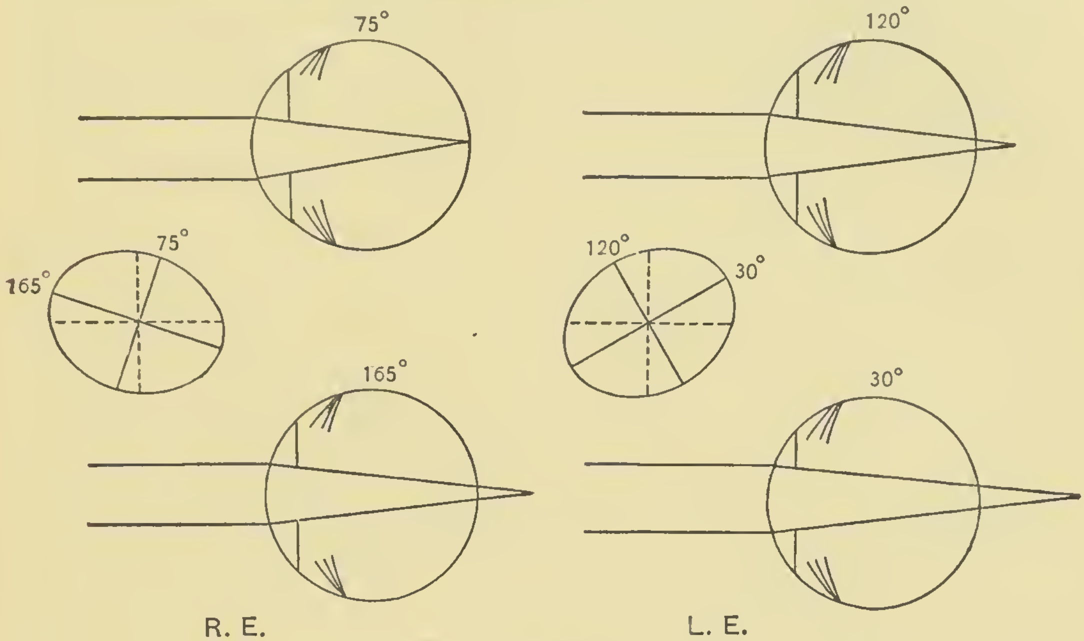


FIG. 46.

This last glass was ordered and has been worn constantly since, with relief from asthenopic symptoms.

CASE XXXII. *Compound hypermetropic astigmatism against the rule in one eye; Large amount of hypermetropia in the other eye; Marked asthenopia; Relief with the use of glasses.* — December 17, 1895, Frances D. M., aged twenty-one, in poor general health, and is very nervous and easily excited or depressed. Her mother was a very nervous woman also. The patient suffers much from fatigue and often has headaches, and her eyes pain after any close work or reading. There is a mild conjunctivitis present.

Ophthalmometer. — Astigmatism against the rule, .25 D., axis 30° + or 120° — right eye; astigmatism with the rule, .50 D., axis 90° + or 180° — left eye.

Test cards and trial lenses.—

R. V. = $\frac{20}{30}$: $\frac{20}{20}$ W. + 3 D. + .75 D. cyl., 30°.

L. V. = $\frac{20}{200}$: $\frac{20}{100}$ W. + 6 D.

Reads Jaeger No. 1 at 6 inches with the right eye, Jaeger No. 4 at the same distance with the left.

Ophthalmoscope.—H. 4 D. at 120° and 3 D. at 30° right eye; H. 7 D. left eye.

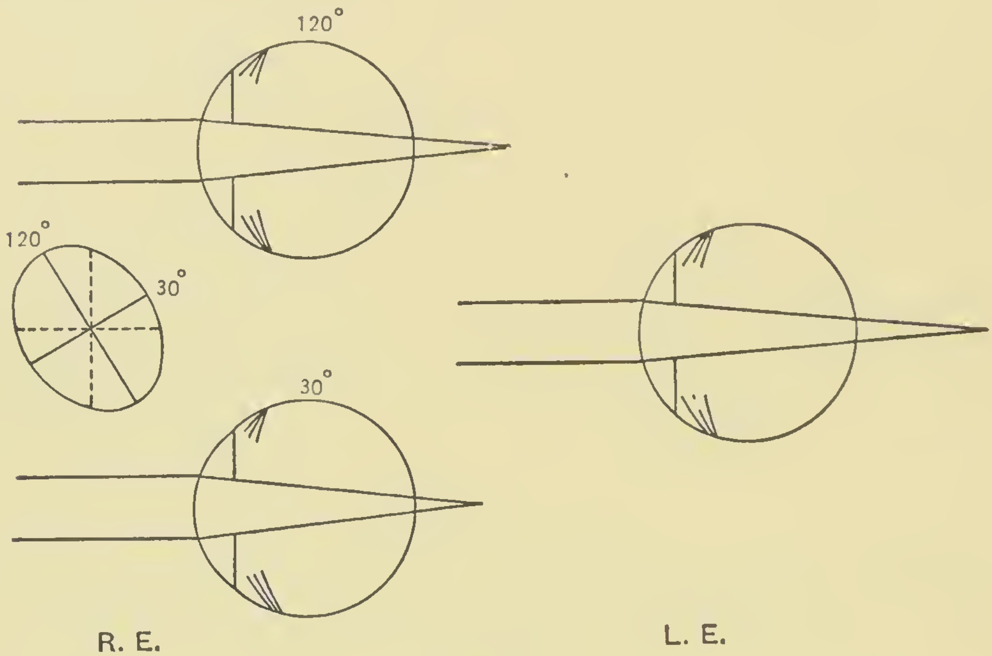


FIG. 47.

The second test resulted in the patient accepting the same glass as at the first test, and they were accordingly ordered. She has worn these glasses for eighteen months with great comfort, though at times she suffers from headaches when greatly exhausted. Her general health has improved considerably, but she is still easily excited.[1]

The ophthalmometer in this case was of great service in pointing out the small amount of astigmatism against the rule, in the right eye, and also the small amount of astigmatism

[1] A note from the patient (June, 1898) informs me that she is still wearing the glasses with comfort, and that her health remains fairly good.

with the rule, in the amblyopic left eye, which was neutralized by the lenticular astigmatism. In fact, had not the ophthalmometer been used in the case, it would have been necessary to have used a mydriatic in order to fit the correct glasses. This would have meant a week or ten days of widely dilated pupils, with much disturbance of vision, to an already excitable and nervous patient, and with no better nor even with as good result, as she had been fitted the year previously under a mydriatic with glasses that were not at all satisfactory.

Case XXXIII. *Compound hypermetropic astigmatism with the chief meridians of curvature at* 45° *and* 135°; *Marked asthenopia*; *Relief with glasses.*— February 25, 1894, Bertha F., aged thirty-nine, in good general health, has had "weak eyes" since a child. When thirteen years old she had "drops," salve, and glasses prescribed. She had but little trouble after that until eight years ago, when the eyes became painful, the eyelids red, and troublesome headaches followed, after using the eyes for close work. She again had salve, "drops," and glasses prescribed, but her eyes have continued painful and the lids red. She now has a well-marked blepharitis marginalis, and is frequently troubled with headaches. I ordered a mild astringent wash and yellow oxide of mercury ointment (2 grains to ℥ii), and after two weeks made the first test for glasses.

Ophthalmometer. — Astigmatism against the rule, 75 D., axis 135° + or 45° − right eye; astigmatism with the rule, 75 D., axis 45° + or 135° − left eye.

Test cards and trial lenses. —

R. V. = $\frac{20}{15}$ − : $\frac{20}{15}$ W. + .75 D. + .25 D. cyl., 135°.

L. V. = $\frac{20}{15}$ − : $\frac{20}{15}$ W. + 1 D. + .25 D. cyl., 45°.

Reads Jaeger No. 1 at 7½ inches.

Ophthalmoscope. — Hypermetropia of 1.50 D. in each eye. It was impossible to estimate the small amount of astigmatism.

Second test, three days later, resulted as follows: Ophthalmometer gave the same reading as on the previous examination.

Test cards and trial lenses. —

R. V. = $\frac{20}{15}$ — : $\frac{20}{15}$ W. + 1.25 D. + .25 D. cyl., 135°.

L. V. = $\frac{20}{15}$ — : $\frac{20}{15}$ W. + 1.25 D. + .25 D. cyl., 45°.

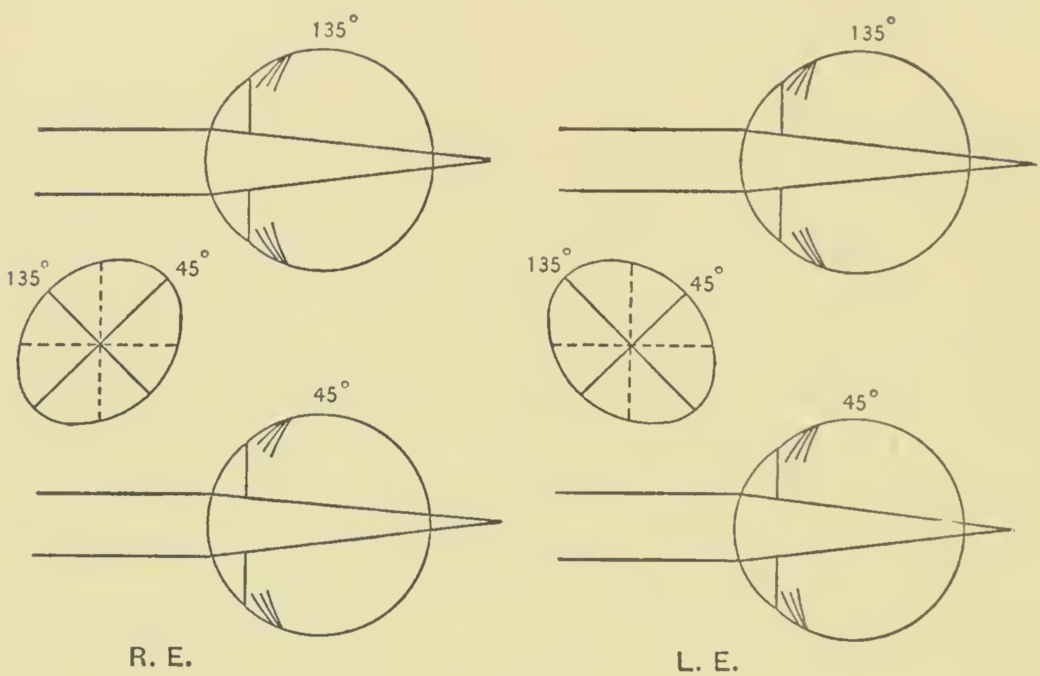


FIG. 48.

The ophthalmoscope showed the same amount of H. as at the first examination. Ordered: —

+ 1.25 D. + .25 D. cyl., 135°;

+ 1.25 D. + .25 D. cyl., 45°.

These glasses have been worn constantly for three and one-half years, and with entire relief of her blepharitis marginalis and freedom from asthenopia. Within a month a + .50 D.s has been added to the distance glasses for reading purposes, on account of presbyopia, she being now 42½ years of age.

Here again the ophthalmometer was of great assistance, for it pointed out the small amount of astigmatism that was present and at the unusual axes of 45° and 135°, — which astigmatism, by the way, had been overlooked at her previous tests under a mydriatic. The instrument read astigmatism against the rule in the right eye and with the rule in the left eye, and an equal amount in each, .75 D. In the right eye, instead of adding .50 D. to the reading of the instrument, as is usual in cases of astigmatism against the rule, .50 D. had to be deducted, just as in the left eye, where the astigmatism was with the rule. It must be remembered here, as I have already pointed out in Chapter II, that, when the chief meridians of curvature are at 45° and 135°, the exact halfway points between 0° and 90° on one side, and 90° and 180° on the other side of the 90°, the terms "with the rule" and "against the rule" do not strictly hold, for the meridians at these points are just as near to 90° as they are to 180°. In other words, they are on the dividing lines between astigmatism with the rule and astigmatism against the rule. Consequently the usual addition of .50 D. to the reading of the instrument, as in astigmatism against the rule, and the subtraction of .50 D. from it, as in astigmatism with the rule, does not hold very strictly in these cases. Knowing the axis of the astigmatism, however, the amount of it, even were it not indicated by the instrument, is usually easily obtained by the subjective test with the trial glasses, especially if the method of beginning the test with the weakest plus glass and gradually increasing it in strength is followed. For instance, in this case I began the subjective test, right eye, with +.25 D. cylindrical glass, axis 135°, which was accepted with improvement in vision. Then +.50 D. cyl., same axis, was tried, but not accepted. Then +.25 D. sphere was added to the +.25 D. cyl., which improved vision. The spherical glass was increased in strength +.25 D. at a time, till the patient accepted +1.25 D.s

in addition to the +.25 D. cyl., axis 135°, which gave him the best vision. Exactly the same course was pursued with the left eye.

I give a second case with axes like the above, but where both the astigmatism and spherical error are much greater in amount and associated with amblyopia.

CASE XXXIV. *Large amount of compound hypermetropic astigmatism with the main meridians at 45° and 135°; Severe asthenopia; Amblyopia; Relief with glasses.* — July 15, 1898. M. B., aged thirty, in good general health, consulted me about her eyes because of great pain in them, and on account of vision blurring when she tried to do any close work. She has always had weak eyes, and has suffered greatly with them, but says she has been afraid to consult an oculist for fear that her sight would be made worse.

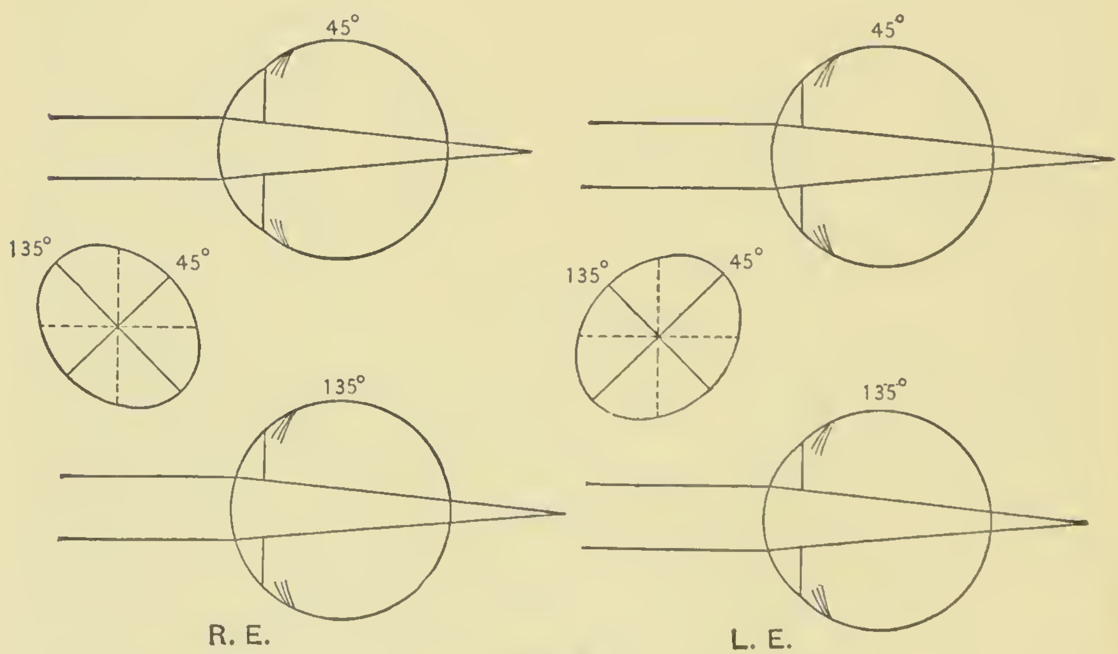


FIG. 49.

Ophthalmometer. — Astigmatism with the rule, 3 D., axis 45° + or 135° – right eye; astigmatism against the rule, 3 D., axis 135° + or 45° – left eye.

It will be noticed in this case that the instrument reads astigmatism with the rule in the right eye, and astigmatism against the rule in the left eye, while it was just the reverse in the preceding case.

This is due to the fact that in each case we started at 135° for the primary position (see rule for procedure in such cases, p. 17). A glance at Figs. 48 and 49 will show why the instrument thus records these cases. In Case XXXIII, right eye, the primary position was at the shortest curved meridian, 135°, consequently when the meridian at 45° was reached, the longest curved meridian, the mires separated, saying "astigmatism against the rule"; while in the left eye the longest curved meridian was at 135°, the primary position, and when the mires were turned to the secondary position, 45°, the shortest curved meridian, they overlapped, saying "astigmatism with the rule." Now in Case XXXIV, right eye, the longest curved meridian was at 135°, consequently when the mires were turned to 45°, the shortest curved meridian, they overlapped, saying "astigmatism with the rule"; while in the left eye the shortest curved meridian was at 135°, and the longest curved meridian at 45°, therefore the instrument read astigmatism against the rule, beginning with 135° as the primary position.

Test cards and trial lenses. —

R. V. = $\frac{20}{200}$: $\frac{20}{40}$ W. + 2.50 D. + 2.75 D. cyl., 45°.

L. V. = $\frac{20}{200}$: $\frac{20}{40}$ W. + 2 D. + 2.75 D. cyl., 135°.

Reads Jaeger No. 1 from 7 to 12 inches.

Ophthalmoscope. — H. 8 D. at 135° and 5 D. at 45° right eye; H. 8 D. at 45° and 5 D. at 135° left eye.

A second test resulted in the patient accepting exactly the same glasses as at the first, and they were accordingly ordered. She has worn these glasses but a few weeks, but as they have relieved her headaches, and enabled her to do

continuous fine needlework, it is fair to presume they will be of permanent benefit.

CASE XXXV. *Astigmatism against the rule in one eye and with the rule in the other; Marked asthenopia; Relief with glasses.* — April 24, 1895, Mr. C. C., aged forty-seven years, in moderately good health, has been unable to get a suitable glass, and that is why he consulted me to-day. The patient received a blow on his right eye with a rubber ball when he was a child, and has never seen very well with that eye since.

Ophthalmometer. — Astigmatism against the rule, .50 D., axis 155° + or 65° – right eye; astigmatism with the rule, .75 D., axis 105° + or 15° – left eye.

Test cards and trial lenses. —

R. V. = $\frac{20}{70}$: $\frac{20}{50}$ W. + 1 D. + 1 D. cyl., 155°.

L. V. = $\frac{20}{20}$: $\frac{20}{15}$ W. + .50 D. + .25 D. cyl., 105°.

Reads Jaeger No. 1 at 8 inches with + 1.50 Ds. added to correct the presbyopia.

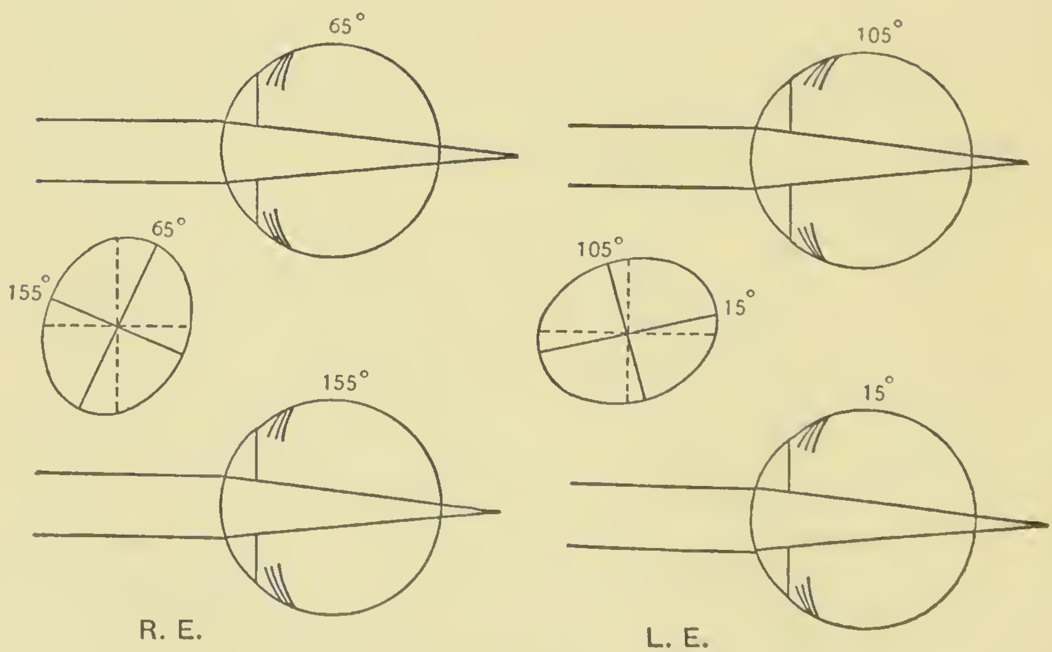


FIG. 50.

Ophthalmoscope. — H. 2 D. at 65° and 1 D. at 155° right eye; H. 1 D. left eye, the astigmatism being too small to estimate with the ophthalmoscope.

The patient accepted the same glasses on a second test that he accepted at first, and both reading and distance glasses were ordered. These glasses have been entirely comfortable, though he has used his eyes continuously in the capacity of a teacher. He was wearing when he came under my care a cylindrical glass at the wrong axis in the right eye, and in the left eye a cylindrical glass four times too strong, which were very good reasons for not having comfortable eyes and good vision.

Case XXXVI. *Ophthalmometer shows no corneal astigmatism; Patient accepts + .25 D. cylindrical glass against the rule in addition to a spherical glass.* — November 29, 1895, Matilda P., aged ten years, in good general health, has for the last year suffered from headaches, burning, and soreness in the eyes after studying for a short time, especially in the afternoon and evening.

Ophthalmometer. — Showed no corneal astigmatism whatever. The lines dividing the mires into halves were straight with each other in all positions, and there was no overlapping or separation of the images after they were once approximated.

Test cards and trial lenses. —

$$\text{R. V.} = \tfrac{20}{40} : \tfrac{20}{20}\ \text{W.} + 1\ \text{D.} + .25\ \text{D. cyl., } 180°.$$

$$\text{L. V.} = \tfrac{20}{40} : \tfrac{20}{20}\ \text{W.} + 1\ \text{D.} + .25\ \text{D. cyl., } 180°.$$

Reads Jaeger No. 1 from 4 to 12 inches.

Ophthalmoscope. — H. 2 D. in each eye. The astigmatism was too small in amount to be estimated with the ophthalmoscope.

A mild astringent wash was ordered for a conjunctivitis that was present, and the patient directed to return in a week for a second test. This test resulted in the patient accepting

the same glasses exactly as at the first, and they were ordered. The patient has been relieved of her headaches and eye symptoms. About eighteen months after the glasses were ordered the patient returned, complaining that her eyes felt tired. With a tonic she was relieved of all eye trouble and without the change of glasses, and she continues her studies with comfort to date, October, 1898.

CASE XXXVII. *The ophthalmometer shows no corneal astigmatism; Patient accepts + .50 D. cylindrical glass against the rule.* — July 19, 1895, Miss J. H. M., aged fifty years, in good general health, consults me on account of pain in the eyes and blurring of the vision on doing close work. She has worn glasses for seven years, but they have not been satisfactory.

Ophthalmometer. — No corneal astigmatism.

Test cards and trial lenses. —

R. V. = $\frac{20}{30}$: $\frac{20}{15}$ W. + .25 D. + .50 D. cyl., 180°.

L. V. = $\frac{20}{30}$: $\frac{20}{15}$ W. + .50 D. + .50 D. cyl., 180°.

Reads Jaeger No. 1 at 8 inches, with a + 2 D.s added to correct her presbyopia.

Ophthalmoscope. — H. 1 D. at 90° and .50 D. at 180° in each eye.

After one test I prescribed the glasses both for distance and for reading. Both have been worn for three years with entire relief from asthenopia.

It will be noticed that the ophthalmometer read negative in the last two cases, or at least it showed no corneal astigmatism; and that in the first case, XXXVI, but + .25 D. cyl. against the rule was accepted; while in the second case, XXXVII, + .50 D. cyl. against the rule was accepted, the customary amount in cases where there is no corneal astigmatism present. The difference in the strength of the cylindrical glasses

accepted by these two patients may be accounted for in part, perhaps, by the fact that in Case XXXVI the patient is a child, in which case the lens is more elastic, the ciliary muscle stronger and possessed of more tonicity than in the older patient, and the muscle acting in an irregular way, as it is known to do sometimes, part of the lenticular astigmatism may be corrected. In Case XXXVII, however, the patient is presbyopic, the lens less elastic, the ciliary muscle weakened, and, therefore, not so likely to correct any of the astigmatism by its irregular action.

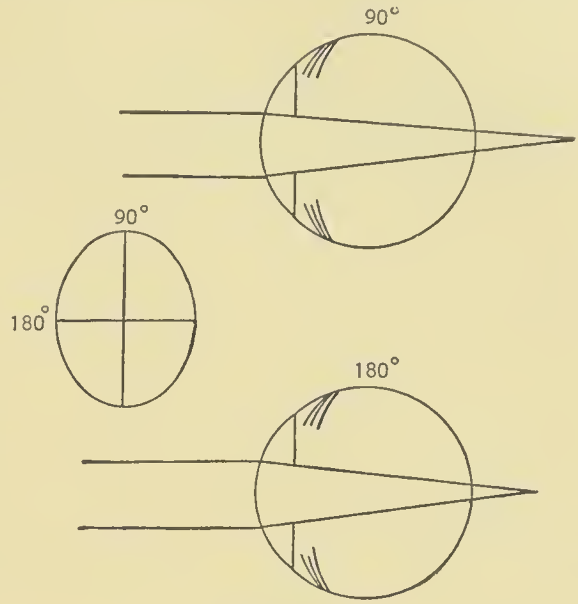


Fig. 51.

I am not unmindful of the fact that lenticular astigmatism is usually ascribed to a tilting position of the lens. But, granting this, still the ciliary muscle might, by its irregular action, correct part of the astigmatism.

I beg to be distinctly understood, however, that I do not advance this idea — the influence of age on the accommodation — to account for the discrepancies, sometimes present, in the readings of the ophthalmometer and the glasses accepted by the patient. I believe it accounts at times for a very small part of the discrepancy. To the more or less tilting of the lens must be ascribed the chief differences in amount in the lenticular astigmatism present. Usually it amounts to just .50 D., but it may be more or less, and at times is absent altogether. Hence the variations that we come across in practice, and which should not disturb us if only a little judgment and common sense are used in accounting for and correcting same.

CASE XXXVIII. *Astigmatism with the rule, .25 D.; Patient accepts + 50 D. cylindrical glass against the rule with relief from marked asthenopia.* — September 18, 1896, Joseph R., aged forty-two years, in good health, has worn glasses for six years. He suffers from headaches, has dazzling sensations before the eyes, and blurring of vision after using his eyes for a short time.

Ophthalmometer. — Astigmatism with the rule, .25 D., axis 105° + or 15° – right eye; astigmatism with the rule, .25 D.,

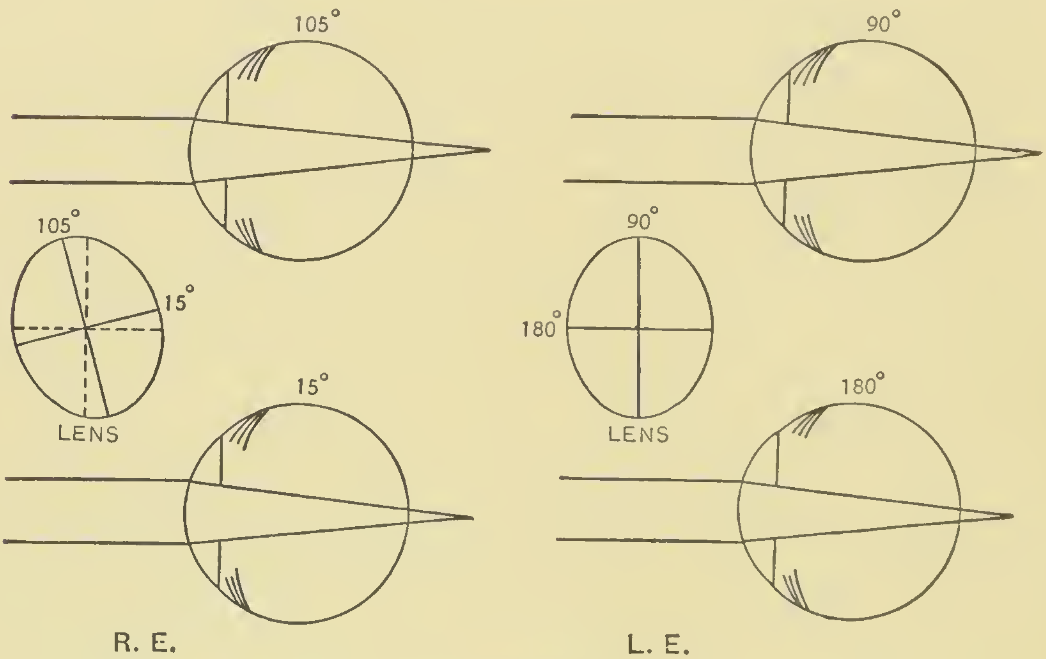


FIG. 52.

axis 90° + or 180° – left eye.

Test cards and trial lenses. —

R. V. = $\frac{20}{30}$: $\frac{20}{15}$ W. + .50 D. + .50 D. cyl., 15°.

L. V. = $\frac{20}{30}$: $\frac{20}{15}$ W. + .50 D. + .50 D. cyl., 180°.

Reads Jaeger No. 1 at 8 inches with + .50 D.s added to correct his presbyopia.

Ophthalmoscope. — H. 1 D. at 105° and H. .50 D. at 15° right eye; H. 1 D. at 90° and H. .50 D. at 180° left eye.

The second test resulted in the patient accepting exactly the same glass as on the first test. Both distance and reading glasses were ordered, and the patient has used his eyes with more comfort than ever before. In fact, has scarcely any trouble, though he uses his eyes steadily.

In this case, while the ophthalmometer read astigmatism with the rule, .25 D., the patient accepted .50 D. cylindrical glass against the rule. This is to be accounted for, I think, by the presence of .75 D. of lenticular astigmatism. The corneal astigmatism of .25 D. neutralized that amount of the lenticular astigmatism, leaving .50 D. of it to be corrected by the glass which the patient accepted.

Case XXXIX. *Ophthalmometer shows corneal astigmatism with the rule, .25 D.; Patient accepts this amount exactly, indicating no lenticular astigmatism whatever.*—May 9, 1895, J. E. H., aged twenty-one years, in good health, has worn glasses for the last four years, but suffers continually with pains in the eyes, headaches, and nervousness. He is a bookkeeper, and the strain on his eyes is great.

Ophthalmometer.—Astigmatism with the rule, .25 D., axis 105° + or 15° − right eye; .25 D., axis 75° + or 165° − left eye.

Test cards and trial lenses.—

$$\text{R. V.} = \tfrac{20}{20} : \tfrac{20}{15} \text{ W.} + 50 \text{ D.} + .25 \text{ D. cyl., } 105°.$$

$$\text{L. V.} = \tfrac{20}{20} : \tfrac{20}{15} \text{ W.} + 50 \text{ D.} + .25 \text{ D. cyl., } 75°.$$

Reads Jaeger No. 1 at 5 inches.

Ophthalmoscope.—H. 1 D. in each eye.

On a second test, the same glass was accepted, and was ordered. With this glass he could follow his calling as a bookkeeper, with comfort. As the patient is a friend, I see him frequently, and he tells me he has none of his old symptoms. He has worn the glasses for two and one-half years.

CASE XL. *Astigmatism with the rule, .25 D.; Patient accepts .50 D. cylindrical glass against the rule, in combination with 2 D.s; Latent hypermetropia of 2 D. left uncorrected; Marked asthenopia; Relief with glasses.* — As regards the astigmatism, this case is similar to Case XXXVIII; that is, the corneal astigmatism of .25 D. is more than neutralized by the lenticular astigmatism, leaving .50 D. of lenticular astigmatism to be corrected by a cylindrical glass.

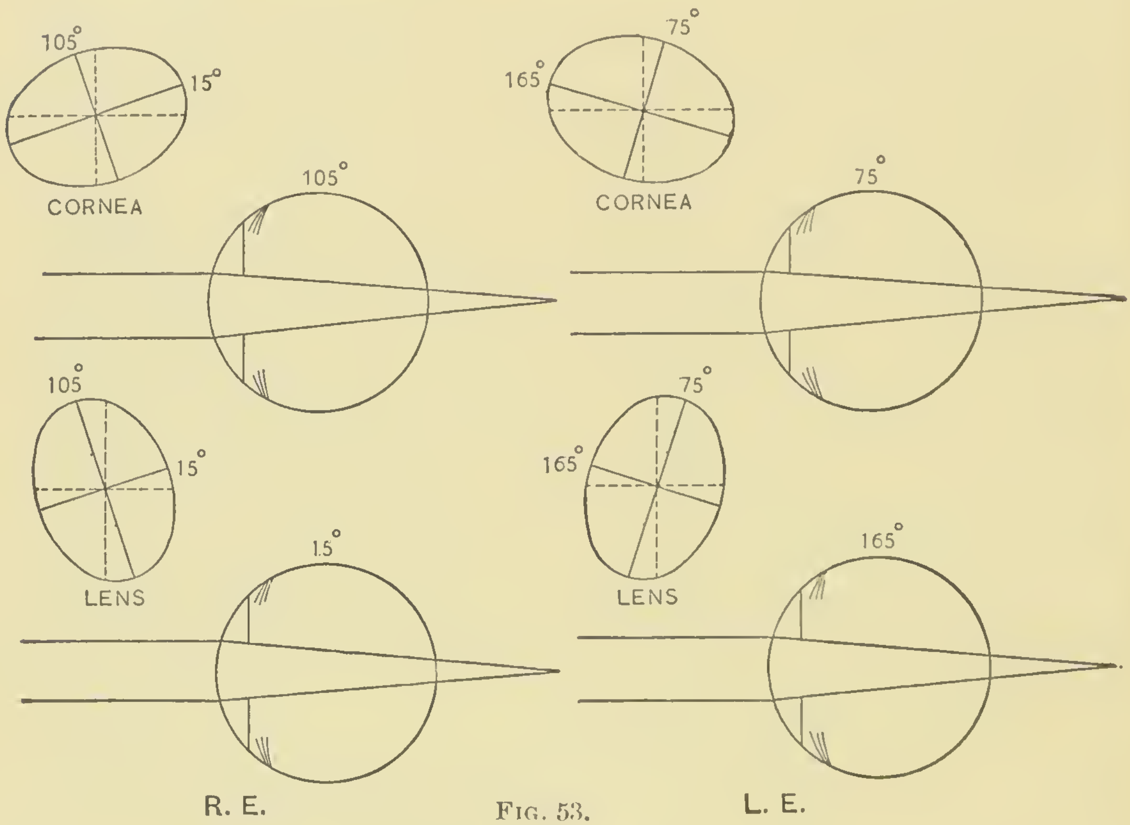


FIG. 53.

May 29, 1894, William E., aged twenty years, in good health, family history good, has been troubled with his eyes since a child. Has headaches, and pains in the eyes after close work of any kind. He fitted himself to glasses five years ago, + 1 D.s, but they have not been satisfactory.

Ophthalmometer. — Astigmatism with the rule, .25 D., axis 105° + or 15° – right eye; 25 D., axis 75° + or 165° – left eye.

Test cards and trial lenses. —

R. V. = $\frac{20}{30}$: $\frac{20}{15}$ W. + 1.50 D. + .50 D. cyl., 15°.

L. V. = $\frac{20}{30}$: $\frac{20}{15}$ W. + 1.50 D. + .25 D. cyl., 165°.

Reads Jaeger No. 1 at 7 inches.

Ophthalmoscope. — H. 4.50 D. at 105° and 4 D. at 15° right eye; H. 4.50 D. at 75° and 4 D. at 165° left eye.

On account of the large amount of latent hypermetropia present in this case, I gave him three tests, each time correcting the astigmatism in each eye separately; then I placed equal-strength spherical glasses in front of each eye at the same time, beginning with + .25 D., and gradually increased their strength up to 2 D., which were as strong as the patient would accept. This spherical glass, in conjunction with the cylindrical ones gave him $\frac{20}{15}$ vision, and they were ordered. Although 2 D. of latent hypermetropia remain uncorrected, these glasses have been worn for two and one-half years with entire relief from his asthenopic symptoms. In passing, it might be remarked that there was no insufficiency of any of the ocular muscles, and no tendency to squint.

CASE XLI. *Astigmatism with the rule*, 1.50 *D. in the right eye*, *and* 2 *D. in the left*, *with* 2 *D. hypermetropia; Fitted with glasses several times under a mydriatic. with but little benefit; Complete relief with glasses fitted by the aid of the ophthalmometer without any mydriatic.* — I report this case in connection with the one preceding, to show that it is unnecessary to make use of mydriatics in the great majority of cases of compound hypermetropic astigmatism, and that a mydriatic may be of harm, as it proved in this case.

June 4, 1896, J. A. R., aged thirty years, is in fairly good health, but has very poor digestion and is not strong.[1] Has had one sister and one brother who died of consumption. The

[1] At this writing, October, 1898, I learn the doctor has developed consumption.

patient is a practicing physician in the West. For the last seven years his eyes have been a source of great annoyance to him. In fact, he has not been able to read or write for more than a few minutes at a time until a severe neuralgic pain would come in the eyes and forehead, so intense that he would have to stop his work. He says this pain was so great at times that it felt as if his eyes were being drawn out of his head. His eyes have been tested by competent men at least one-half dozen times under the influence of a mydriatic, but none of the glasses prescribed gave him anything more than partial relief, and then only for a short time. He has suffered greatly from photophobia, and of two oculists of this city whom he consulted besides myself, one was of the opinion that his chief trouble was "hyperæsthesia of the retina," and advised no change of glasses from those he was already wearing. The other oculist whom he consulted, tested his eyes without the use of a mydriatic. His test and my own, made independently, agreed exactly in one eye, and differed but .25 D. in strength in the spherical glass in the other eye. No muscle insufficiencies were present.

Ophthalmometer. — Astigmatism with the rule, 1.50 D., axis 90° + or 180° − right eye; 2 D., axis 90° + or 180° − left eye.

Test cards and trial lenses. —

R. V. = $\frac{20}{30}$: $\frac{20}{15}$ W. + .50 D. + 1.25 D. cyl., 90°.

L. V. = $\frac{20}{100}$: $\frac{20}{15}$ W. + .50 D. + 1.75 D. cyl., 90°.

Reads Jaeger No. 1 at 6 inches.

Ophthalmoscope. — H. 1.50 D. at 90° and 2.50 D. at 180° right eye; H. 1.50 D. at 90° and 3 D. at 180° left eye. Besides a slight hyperæmia of the retina, the fundus was normal in each eye.

Second test: the ophthalmometer read the same as on the first test.

Test cards and trial lenses. —

R. V. = $\frac{20}{30}$: $\frac{20}{10}$ – W. + 1 D. + 1.25 D. cyl., 90°.

L. V. = $\frac{20}{100}$: $\frac{20}{10}$ – W. + 1.25 D. + 1.75 D. cyl., 90°.

Reads Jaeger No. 1 at 6 inches.

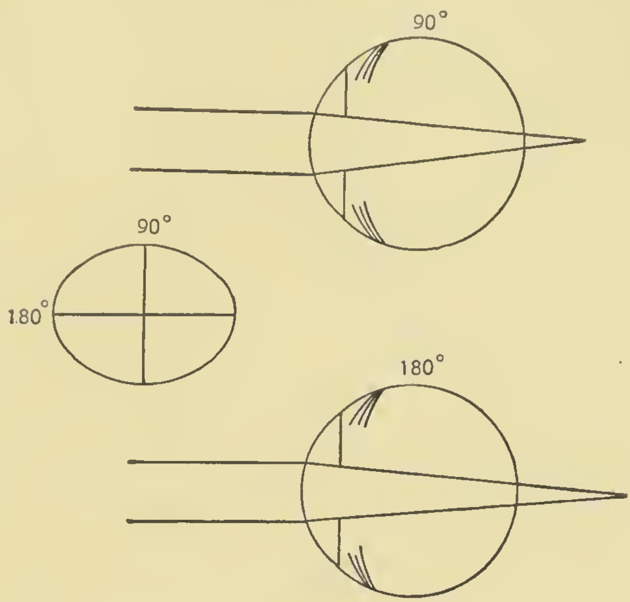


FIG. 54.

Ophthalmoscope. — Shows the same as at the first test.

A third test resulted in the patient accepting exactly the same glasses as on the second test, and they were ordered. These glasses gave him entire relief from his asthenopic symptoms, and he was able to use his eyes with comfort for long hours for the first time in seven years. It is now more than two years since he was ordered these glasses, and they are still satisfactory.

He was wearing when he came to see me + 1.75 D. + .75 D. cyl., 90° right eye, and + 1.75 D. + 1.25 D. cyl., 90° left eye. Atropine in the hands of a half dozen competent men had been a failure in his case, simply because they overfitted the spherical error and underfitted the astigmatic error.

Roosa, long ago, pointed out the fact that in young sub-

jects we may often leave one, two, and in some cases even as much as three, diopters of latent hypermetropia uncorrected without harm. Especially, I think, in those cases where the astigmatism is large in amount and the latent hypermetropia small or only moderately large in amount, it is safe to let the latent hypermetropia go uncorrected. The younger the subject, the more latent hypermetropia may be left without harm. The following is a good example of this class of cases.

CASE XLII. *Astigmatism of large amount, with moderately large amount of latent hypermetropia, which latter was left uncorrected; Complete relief of the asthenopia by correction of the astigmatism.* — October 6, 1893, Alma S., aged twenty-four years, in good health, has had trouble with her eyes since childhood, but has never had them examined. Her eyes pain and her head aches after she uses the eyes for any close work; in fact, she cannot use the eyes for more than a short time without resting them, particularly in the evening.

Ophthalmometer. — Astigmatism with the rule, 5 D., axis 60° + or 150° − right eye; 5 D., axis 105° + or 15° − left eye.

Test cards and trial lenses. —

R. V. = $\frac{20}{70}$: $\frac{20}{30}$ W. + 4.25 D. cyl., 60°.

L. V. = $\frac{20}{70}$: $\frac{20}{30}$ W. + 4.25 D. cyl., 105°.

Reads Jaeger No. 1 at 6 inches.

Ophthalmoscope. — H. 2.50 D. at 60° and 6.50 D at 150° right eye; H. 1.50 D. at 105° and 6 D. at 15° left eye.

On a second test the patient accepted exactly the same glasses as at the first test, and they were ordered. They have been worn constantly since, with relief of the asthenopic symptoms from which she suffered. In this case a latent hypermetropia of about 2 D. was left uncorrected in each eye.

While these last few cases have been given to emphasize the fact that it is not necessary to use a mydriatic in the great majority of cases, even where there is considerable amount of

latent hypermetropia present, yet there are exceptional circumstances under which a mydriatic is necessary in order to fit glasses. I refer to spasm of accommodation.

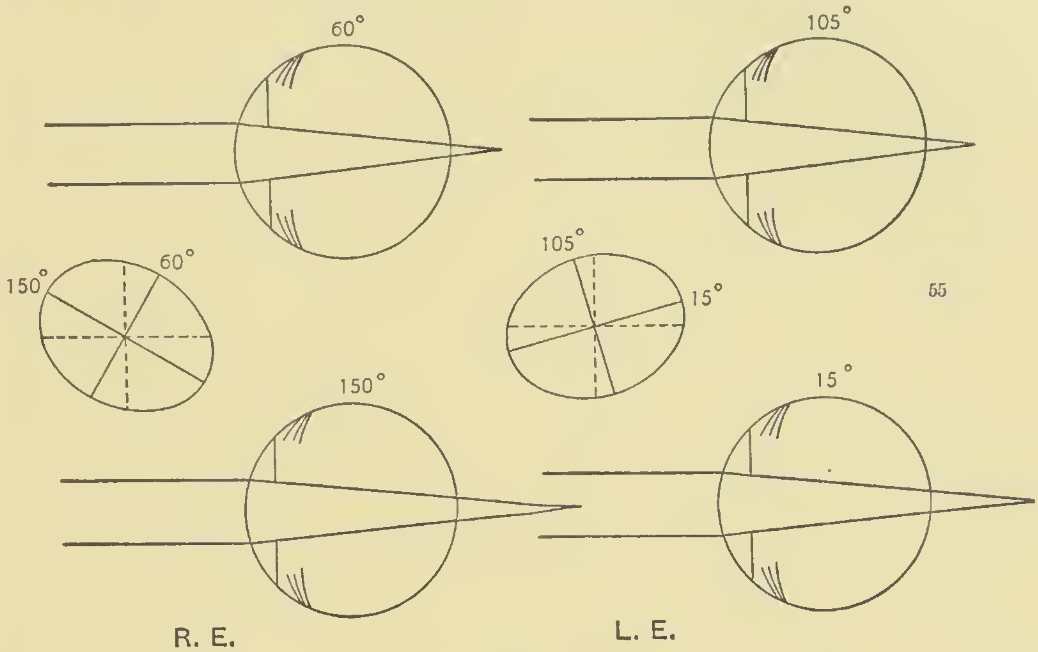


FIG. 55.

SPASM OF ACCOMMODATION

Spasm of accommodation may be present in any form of error of refraction, but it is met with more frequently in hypermetropia, hypermetropic astigmatism, and mixed astigmatism, than in myopic cases. Fortunately, spasm of accommodation is a comparatively rare condition, and the cases where it is necessary to use a mydriatic to suspend the accommodation are very few.[1]

In support of this statement the reader is referred to papers by Roosa,[2] George J. Bull,[3] of Paris, myself,[4] and to

[1] Of course strabismus cases are here excluded. They will be discussed in a separate chapter.

[2] *Trans. Med. Soc.*, state of New York, February, 1891.

[3] *Ophthalmic Review*, London, September, 1895.

[4] *New York Medical Journal*, September 10 and October 8, 1892, and June 20, 1896.

the writings of American and European oculists in the last few years.

Let me, also, emphasize the fact that it is not necessary to use a mydriatic in every case of spasm of accommodation: for, in many cases of spasm of accommodation, if the cause for it is found out and removed, the spasm disappears. Two questions of importance are to be considered in discussing spasm of accommodation: first, how to recognize it; second, how to treat it, especially in regard to fitting glasses.

How to recognize spasm of accommodation. — The most important of the *subjective* symptoms are: (1) Sudden variability in vision in reading the test cards for distant vision. For example, testing one eye at a time, the patient reads all of the letters on the Snellen card down to and including the $\frac{20}{30}$ line, when suddenly the letters fade out, and the patient is not able to read more than $\frac{20}{100}$ perhaps. Allow the patient to rest a moment with the eyes closed, then repeat the test, and the same thing will likely happen again. This condition may be present in only one eye, but usually it is present in both, if present at all. This sudden failure of the vision is evidently due to sudden contraction or spasm of the ciliary muscle, which allows the crystalline lens to expand, and the eye to become temporarily myopic (false or spasmodic myopia). This condition, of course, makes the distant vision bad. (2) Changeableness in appearance of the lines on the clock-dial. For instance, say we have a case of simple hypermetropic astigmatism with the rule, and a tendency to spasm of accommodation. This patient when he first looks at the clock-dial may see the horizontal lines plainest (as he should if no spasm of accommodation was present), but in a moment the vertical lines appear plainest and the horizontal lines become dim. Evidently in such case the spasm of the ciliary muscle has converted the simple hypermetropic astigmatism into a myopic astigmatism with the rule, for in myopic astigmatism with the

rule the vertical lines are seen plainest. (3) A sense of contraction or drawing in the eyeball is felt. (4) Variability in the glasses accepted by the patient during the test, *e.g.*, a patient accepts a plus glass one minute and in the next refuses it, or, perhaps, accepts a minus glass, quickly changing from one to the other; or, he may accept a strong plus glass one minute and only a weak one the next.

The *objective* symptoms are: (1) Where the ophthalmoscopic examination shows the refractive condition of the eye to be widely different from the glasses accepted on subjective examinations. For instance, the patient has accepted + 1 D. spherical glasses when the ophthalmoscope shows him to be hypermetropic by 5 D. Or, say the patient has accepted − 1 D. spherical glasses when the ophthalmoscope shows him to be actually hypermetropic. Not infrequently the patient will relax his spasm of accommodation under an ophthalmoscopic examination when he will not under a subjective examination. This I think due chiefly to the fact that under an ophthalmoscopic examination the patient is in a dark room, with pupils dilated, and looking in the distance at nothing in particular, having nothing, therefore, to stimulate his accommodation; while, under a subjective examination, the patient is looking intently at letters, trying to figure them out, and this of itself many times incites the ciliary muscle to action. (2) Where the retinoscope shows sudden changes in the refractive condition of the eye, perhaps indicating hypermetropia one instant and myopia the next, and where the glasses accepted by the retinoscopic test do not give uniform good vision. (3) In cases of astigmatism where the glasses accepted vary widely from the reading of the ophthalmometer, it is often an indication of spasm of accommodation.

The above are the chief symptoms of spasm of accommodation, and, as a rule, the condition is easily recognized by them, many times by means of only one or two of them.

Of the subjective symptoms, the sudden change in the acuteness of vision is the most constant and reliable one; and of the objective symptoms, that discovered by the ophthalmoscope is the most reliable one.

How to overcome spasm of accommodation.—When once satisfied that there is a spasm of accommodation, or a tendency to it, I look for the cause, and try to remove that, before I hastily resort to the use of some mydriatic. For, even though we do use a mydriatic and fit the patient, the patient is often unable to wear the glasses unless the cause of spasm is gotten rid of. Unless, indeed, as has been recommended and practiced by some oculists in this country, atropine is continued for weeks after the glasses have been fitted, which, in my opinion, is altogether bad practice. The much better plan is to seek for and remove the cause. Failing in that, then mydriatics are called for, but not until then. In exceptional cases, no apparent cause can be discovered to account for spasm of accommodation.

Some of the most prominent causes of spasm of accommodation are: (1) conjunctivitis; (2) insufficiency of the internal recti muscles; (3) contusion; (4) sympathetic irritation, though many times contusion and sympathetic irritation are accompanied with paresis of accommodation; (5) generalized spasmodic affections; (6) overwork of the eyes; (7) hyperæsthesia of the retina; (8) beginning the test for glasses with minus glasses; (9) idiopathic cases.

These are the chief causes of spasm of accommodation. Many times, where the test for glasses at first has been unsatisfactory, and a tendency to spasm, or actual spasm, of accommodation was present, I have succeeded in fitting glasses by first treating the lids for a week or ten days with a mild astringent wash. A conjunctivitis of a mild type will often cause enough irritation of the ciliary muscle to render a test for glasses unsatisfactory. Again, where the patient

has been using the eyes excessively for a day or two before coming for a test, it is often necessary to make him rest the eyes or use them easily for a day or two, before giving the final test. In hyperæsthesia of the retina, shaded glasses worn for a few days before the test is desirable. If insufficiency of the internal recti muscles is present, a week or two of treatment with strych. sulphate, in increasing doses, with outdoor exercise and rest, will usually suffice to relieve it, and leave the eyes in condition for testing.[1]

So with the other causes of spasm of accommodation when present, I try to remove them. If no apparent cause is to be found, and if the second test for the glasses is not satisfactory, and does not substantially agree with the first, I do not hesitate to use a mydriatic, and a strong one. Scopolamine and atropine are the two I employ. The method of their use I have already pointed out in the first part of this chapter.

I now give some cases illustrative of the condition of spasm of accommodation.

CASE XLIII. *Compound hypermetropic astigmatism with the rule; Spasm of accommodation; Amblyopia; Atropine used, and but little difference found between the glasses fitted without atropine and those fitted under it.* — June 25, 1894, Gussie L., aged fifteen, is in poor general health. Her eyes have troubled her since six years of age, when she entered school. She was never able to see the blackboard well, was nervous, and found it hard to sit still for any great length of time. At present she has headaches, and pains in the eyes on using them for close work.

Ophthalmometer. — Astigmatism with the rule, 1.50 D., axis 90° + or 180° – in each eye.

[1] For the methods of testing the strength of the external ocular muscles, see the chapter on Strabismus.

Test cards and trial lenses. — The lines on the clock-dial were entirely unsatisfactory as a test.

R. V. = $\frac{10}{200}$: $\frac{20}{100}$ W. – 2 D – 1 D. cyl., 180°.

L. V. = $\frac{10}{200}$: $\frac{20}{100}$ W. – 2 D – 1 D. cyl., 180°.

During the test there were signs of spasm of accommodation, for first one set of lines on the clock-dial would appear plainest, then another set; and the vision at one moment would be fairly good and the next moment very poor. I therefore began to test both eyes at once, even for the astigmatism, and as the ophthalmometer showed it to be exactly the same in each eye, it was easy to do so. Placing + .25 D. cyl., 90°, before each eye, the vision was somewhat improved, and I gradually increased the strength up to + 1 D. cyl., the vision improving *para passu.* With a stronger + cyl. the vision was not so good as with the + 1 D. cyl., so I stopped at that point. With the cylindrical glasses in position, weak plus spherical glasses were tried before both eyes at once with improvement in vision, and they were gradually increased up to + 1 D. sphere. Testing in this way both eyes at the same time, the patient accepted + 1 D. + 1 D. cyl., 90°, and the vision was brought up to $\frac{20}{70}$ in each eye.

Ophthalmoscope. — H. 2 D. at 90° and 3.50 D. at 180° in each eye.

Atropia sulphate, solution of four grains to one ounce, was ordered instilled, one drop in each eye three times a day for four days, and then a second test was made.

The ophthalmometer read exactly the same as at the first test.

Test cards and trial lenses. —

R. V. = $\frac{20}{200}$: $\frac{20}{50}$ W. + 2 D. + 1.25 D. cyl., 90°.

L. V. = $\frac{20}{200}$: $\frac{20}{50}$ W. + 1.50 D. + 1.25 D. cyl., 90°.

Ophthalmoscope. — H. 2 D. at 90° and 3.50 D. at 180° right eye; H. 1 D. at 90° and 2.50 D. at 180° left eye. Retinoscopy confirmed the other tests.

One week after the test under atropine, the patient was subjected to a third test. She accepted + 1.25 D. + 1.25 D. cyl. at 90° right eye, and + 1 D. + 1.25 D. cyl. at 90° left eye, and these glasses were ordered. It will be noticed that they differ but slightly from the ones that the patient accepted before atropine was used, that is, when both eyes were tested at once. In fact, they differ so little that I believe she would have been almost, if not quite, as comfortable with the former as she is now with the latter, which give her entire relief from her asthenopia. Her poor vision, however, which later I found to be due simply to amblyopia, and the fact of her accepting minus glasses at first when the eyes were tested separately, induced me to use a mydriatic. Under tonics and outdoor exercise her general health improved.

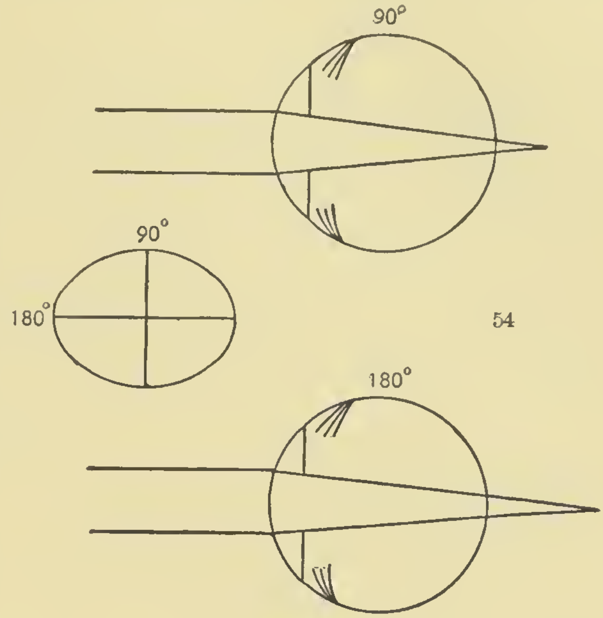


Fig. 56.

Case XLIV. *Compound hypermetropic astigmatism against the rule; Spasm of accommodation; Mild conjunctivitis; Hyperæsthesia of the retinæ; Scopolamine used.* — November 20, 1895, Miss C. A. F., aged twenty-two years, in good general health, consulted me first for a catarrhal conjunctivitis. She states that about two years ago she had a very severe inflammation in the eyes following measles, and was confined to a darkened room for five months on account of the light which

hurt her eyes. She had glasses fitted shortly afterward, but her eyes have continued to pain her.

Ophthalmometer. — Shows no corneal astigmatism.

Test cards and trial lenses. —

$$\text{R. V.} = \tfrac{20}{20} - : \tfrac{20}{20}\ \text{W.} + .25\ \text{D. cyl., } 180°.$$

$$\text{L. V.} = \tfrac{20}{30} \quad : \tfrac{20}{20}\ \text{W.} + .25\ \text{D. cyl., } 180°.$$

Reads Jaeger No. 1 at 4 inches.

Ophthalmoscope. — H. 1 D. in each eye; no astigmatism could be estimated with the ophthalmoscope.

Although both eyes were tested at the same time, the patient would not accept any stronger glasses. Neither was retinoscopy of benefit in fitting the case. During the test the patient would be able to read $\frac{20}{20}$ at one moment, then the vision would blur and she could not read more than $\frac{20}{40}$. She also complained of drawing sensations in the eyes.

Scopolamine, $\frac{1}{5}$ per cent solution, was instilled, one drop in each eye every five minutes for six successive times, and then after a wait of half an hour a second test was made.

Second test, under scopolamine.

Ophthalmometer. — No corneal astigmatism.

Test cards and trial lenses. —

$$\text{R. V.} = \tfrac{20}{50} : \tfrac{20}{20}\ \text{W.} + 1\ \text{D.} + .25\ \text{D. cyl., } 15°.$$

$$\text{L. V.} = \tfrac{20}{70} : \tfrac{20}{20}\ \text{W.} + 1\ \text{D.} + .25\ \text{D. cyl., } 165°.$$

Ophthalmoscope. — Showed the same amount of H. as at the first test.

Three days later, when the patient was out from under the influence of the mydriatic, a third test was made, with the following result: —

$$\text{R. V.} = \tfrac{20}{20} - : \tfrac{20}{20}\ \text{W.} + .25\ \text{D.} + .25\ \text{D. cyl., } 15°.$$

$$\text{L. V.} = \tfrac{20}{30} \quad : \tfrac{20}{20}\ \text{W.} + .25\ \text{D.} + .25\ \text{D. cyl., } 165°.$$

This last glass was prescribed, and the patient had almost immediate relief from her asthenopia, although it required weeks to relieve the photophobia. In fact, a bright light, as the glare of the sun on the water, still troubles her considerably.

CASE XLV. *Hypermetropia of large amount; Spasm of accommodation; Asthenopia; Atropine used; Relief with 3 D. of latent hypermetropia left uncorrected.* — June 16, 1896, Bella K., aged fourteen, in good health, complains of her eyes hurting her when she tries to do close work, and of a drawing sensation in the eyes at times. She has always had "weak eyes" and often suffers from headaches.

Ophthalmometer. — Astigmatism with the rule, .25 D., axis 105° + or 15° – right eye; .25 D., axis 75° + or 165° – left eye.

Test cards and trial lenses. —

R. V. = $\frac{20}{20}$ – : $\frac{20}{15}$ W. + .50 D. + .25 D. cyl., 105°.

L. V. = $\frac{20}{40}$ – : $\frac{20}{20}$ W. + 1 D. + .25 D. cyl., 75°.

Reads Jaeger No. 1 from 4 to 16 inches.

Ophthalmoscope. — H. 3 D. in each eye.

As the patient had signs of spasm of accommodation, first being able to read well then the vision blurring, sense of contraction in the eyes, accepting a weak cylindrical glass and then refusing it, etc., I decided to use a mydriatic, especially as the ophthalmoscope showed at least three diopters of hypermetropia. Atropine, 4 gr. to ℥ i sol., was ordered instilled, one drop three times a day for three days.

Second test, under atropine.

Ophthalmometer gave the same reading as at the first test.

Test cards and trial lenses. —

R. V. = $\frac{20}{200}$: $\frac{20}{15}$ – W. + 5 D.

L. V. = $\frac{20}{200}$: $\frac{20}{15}$ – W. + 5.50 D.

Ophthalmoscope.—H. 5 D. right eye; H. 6 D. left eye.

Third test, one week later, the patient accepted + 2 D. right eye and + 2.50 D. left eye. These glasses were ordered, and though they left about three diopters of hypermetropia in each eye uncorrected, yet they have been worn with comfort and relief from asthenopic symptoms for a period of two years. This patient would not relax the accommodation when both eyes were tested at once, and even after being under atropine and coming out she yet had 3 D. of latent hypermetropia. Nevertheless, since with + 2 D. right and + 2.50 D. left the vision was $\frac{20}{15}$ – and steady, without signs of spasm of accommodation, I left the latent hypermetropia to take care of itself.

I make this distinction between spasm of accommodation and latent hypermetropia. In spasm of accommodation the vision is variable, that is, it changes from one moment to another, often with sensations of drawing in the eyes, and the ophthalmoscopic and retinoscopic examinations show the refraction to vary; while in latent hypermetropia the ciliary muscle is able to and does correct steadily and without irregular action that portion of the total hypermetropia which is latent. As long as the ciliary muscle can do this with comfort and without strain, the latent hypermetropia remains practically the same, at least does not vary suddenly, and the subjective examinations do not discover it, unless when for some special reason we use a mydriatic. As the patient grows older, however, or becomes ill or overworked, the ciliary muscle may not be able to keep up its steady action, and begins to manifest signs of fatigue and to act irregularly, or with spasmodic action, if you please, with the result of variability in vision, a sensation of drawing in the eyes, headaches, etc. It is at this time that aid to the ciliary muscle is called for and should be given, but as long as an eye can work with comfort, and without bother to the patient, I believe it good policy to let it alone.

I shall give here also a single case of spasm of accommodation occurring in simple hypermetropic astigmatism ; but for cases of spasm of accommodation occurring in myopia, myopic astigmatism, and mixed astigmatism, I shall give them when treating those subjects.

Case XLVI. *Simple hypermetropic astigmatism; Spasm of accommodation; Marked asthenopia; Minus cylindrical glasses accepted without atropine and perfect vision obtained; Plus cylindrical glasses accepted under atropine and perfect vision.* — April 5, 1892, Herminia T., aged nineteen years, in good health, has been troubled with her eyes for the last four years, in fact, more or less ever since she entered school. She cannot read or sew for any great length of time without getting pain in the eyes, and if she persists in her work her head aches. Some slight injection of the conjunctiva.

Ophthalmometer. — Astigmatism with the rule, 1.25 D., axis 90° + or 180° − each eye.

Test cards and trial lenses. — The vertical lines on the clock-dial appeared plainest.

R. V. = $\frac{20}{30}$: $\frac{20}{15}$ − W. − .75 D. cyl., 180°.

L. V. = $\frac{20}{30}$: $\frac{20}{15}$ − W. − .75 D. cyl., 180°.

Reads Jaeger No. 1 from 6 to 15 inches.

Ophthalmoscope. — Emmetropia vertical meridian (90°) and H. .50 D. in horizontal meridian (180°) in each eye.

Although both eyes were tried at once, the patient would accept nothing but minus glasses. Retinoscopy indicated myopic astigmatism. A wash was prescribed for the mild conjunctivitis, the patient ordered not to use the eyes so hard, and to report in a week. A second test was given, with exactly the same result as on the first test. Signs of spasm of accommodation were present. Atropine, solution 4 gr. to ℥i, was ordered instilled, one drop three times a day for three days.

Test under atropine: ophthalmometer read the same as on the two previous tests.

Test cards and trial lenses. — The horizontal lines on the clock-dial were seen plainest now.

$$\text{R. V.} = \tfrac{20}{50} : \tfrac{20}{15} - \text{W.} + .75 \text{ D. cyl., } 90°.$$

$$\text{L. V.} = \tfrac{20}{50} : \tfrac{20}{15} - \text{W.} + .75 \text{ D. cyl., } 90°.$$

A week later, when the effect of atropine was out of the eye, the patient again accepted + .75 D. cylindrical glass, axis

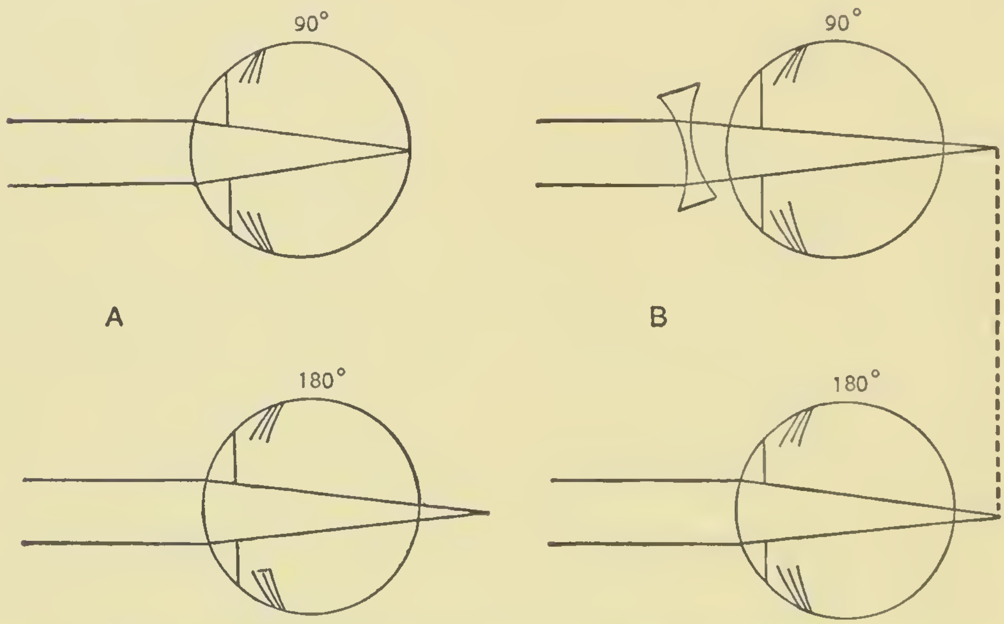


FIG. 57. — Showing how a simple minus cylindrical glass can convert a simple hypermetropic astigmatism into simple hypermetropia.

90,° in each eye, and it was ordered. These glasses have been worn for more than four years, and with relief from her asthenopic symptoms.

In some cases of simple hypermetropic astigmatism a patient will accept a minus cylindrical glass and get relief from all asthenopic symptoms. This is to be explained, I think, by the fact that the patient, in accepting a simple myopic cylindrical glass, converts the simple hypermetropic astigmatism into a simple hypermetropia (see Fig. 57). By so doing, the

ciliary muscle can then act in its entire circumference and correct the simple hypermetropia of small amount with ease and without fatigue ; whereas it could not correct an equal amount of simple hypermetropic astigmatism, because, in that instance, it would be compelled to contract irregularly, and in that way cause asthenopia or painful vision.

CHAPTER V

SIMPLE MYOPIC ASTIGMATISM — MYOPIA — SPASMODIC OR FALSE MYOPIA — RULE FOR PRESCRIBING NEAR OR READING GLASSES IN HIGH DEGREES OF MYOPIA — PRESBYOPIA AND THE TRANSPOSITION OF GLASSES FROM DISTANCE TO READING IN MYOPES WHEN IT IS PRESENT

The ophthalmometer, except in an indirect way already discussed in a previous chapter, does not reveal the nature of the error of refraction. This has to be found out with the trial case and test cards, the ophthalmoscope and retinoscope. So in myopia we make the same measurements with the ophthalmometer as in all other cases. Furthermore, I begin the test with plus glasses just as I do in all cases, because, not knowing the nature of the error of refraction, it is safe to begin only with plus glasses. Should the patient prove to be hypermetropic, and minus glasses are tried first, they often incite a spasm of accommodation and are accepted when they should not be; while, if plus glasses are begun with, we can be sure they will not be accepted by a myope, and we can find this out by the trial of only two or three glasses and without the risk of inciting spasm of accommodation. Of course, if the ophthalmoscope is used before glasses are tried, that indicates the kind of glass to be tried first. As a rule, however, I prefer not to make an ophthalmoscopic examination until I have tried the test cards and trial case, because, if light is thrown into the eyes for any considerable time just before testing the vision, it often impairs the value of the test.

Perhaps before giving illustrative cases it is well to make a clear distinction here between true or axial myopia and false

or spasmodic myopia. True myopia is where the axis of the eye is too long, allowing the rays of light to focus in front of the retina (see Fig. 58). This may be small or large in amount, according to the increase of length of the eyeball beyond the length of the emmetropic eye, which latter is about 23 mm. When the eye becomes elongated rapidly, attended with changes in the choroid and sclera, with posterior staphyloma, etc., we call this progressive or malignant myopia.

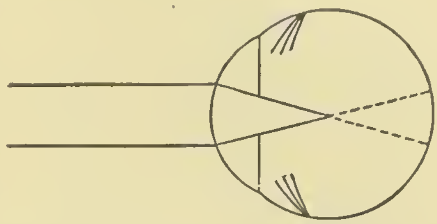


FIG. 58. — True or axial myopia, parallel rays focussing in front of the retina, crossing and forming diffusion circles on the retina.

False myopia is nothing more than a spasm of the ciliary or focussing muscle. To illustrate, say the patient is emmetropic, but from some cause the ciliary muscle is overacting. By so doing the eye is rendered myopic by the lens becoming thicker. and causing the rays to focus in front of the retina. Furthermore, this patient would accept minus glasses with improvement in vision, as long as this spasm of accommodation lasted.

False myopia may be present even in hypermetropia, the focus being changed from back of the retina to the front of it by the spasm of accommodation. Again, false myopia may be present in the same eye with true myopia, that is, the spasm of accommodation increases the true myopia.

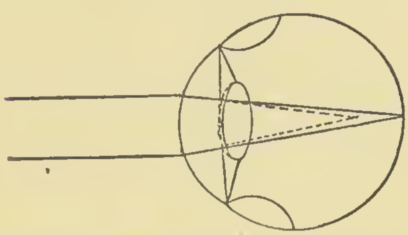


FIG. 59. — False myopia in an emmetropic eye, due to spasm of accommodation. Dotted line shows false focus.

It is altogether important to recognize the difference between true and false myopia; for, while the true myopia should be carefully corrected, false myopia should never have a glass prescribed for it, but its cause should be looked for and remedied, if possible, upon which it disappears and requires no further treatment.

Of *curvature* myopia it is hardly worth while to speak, more than to say that such a thing exists. It is due to excessive curvature of the cornea, and not to lengthening of the eyeball (see Fig. 60).

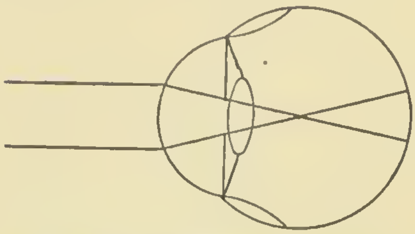


Fig. 60. — Curvature myopia, where the length of the eyeball is normal, but the cornea is too much curved.

It is a rare error of refraction, and when present is usually due to some pathological condition. conical cornea, staphyloma of the cornea, etc., for which conditions glasses are of but little benefit.

Of the rule of procedure in giving distance and reading glasses in high degrees of myopia, and of the transposition of glasses in presbyopia in myopic cases, I shall speak later in this chapter, giving appropriate illustrative cases.

Case XLVII. *Simple myopic astigmatism with the rule; Blepharitis marginalis; Slight asthenopia; Relief of blepharitis with use of glasses and local treatment.* — October 26, 1896, Charles Q., aged twenty-nine years, in good health, always had poor vision, and for the last four years his eyelids got red at the edges when he used his eyes for close work of any kind. There is but little pain in the eyes, but the lids itch and burn. He has no headaches.

Ophthalmometer. — Astigmatism with the rule, 3 D., axis 90° + or 180° – in each eye.

Test cards and trial lenses. —

$$\text{R. V.} = \tfrac{20}{50} : \tfrac{20}{15} \text{ W.} - 2.50 \text{ D. cyl., } 180°.$$

$$\text{L. V.} = \tfrac{20}{50} : \tfrac{20}{15} \text{ W.} - 2.50 \text{ D. cyl., } 180°.$$

Reads Jaeger No. 1 at 12 inches.

Ophthalmoscope. — Myopia 3 D. at 90° and emmetropia at 180° in each eye.

A wash of boracic acid solution was ordered to cleanse the

lids with twice a day, and an ointment of yellow oxide of mercury, eight grains to one ounce of vaseline, to rub on the eyelids at night.

Two weeks later the lids were very much improved in appearance. A second test for glasses was made, and the patient accepted exactly the same glasses as at the first test. Ordered − 2.50 D. cyl., 180°, for each eye, which have been worn with an entire relief from the lid trouble.

In this case, the test was begun with plus cylindrical glasses, just as I do in all cases where the ophthalmometer indicates astigmatism, but, as vision was made worse, minus cylindrical glasses were immediately tried and with improvement in vision.

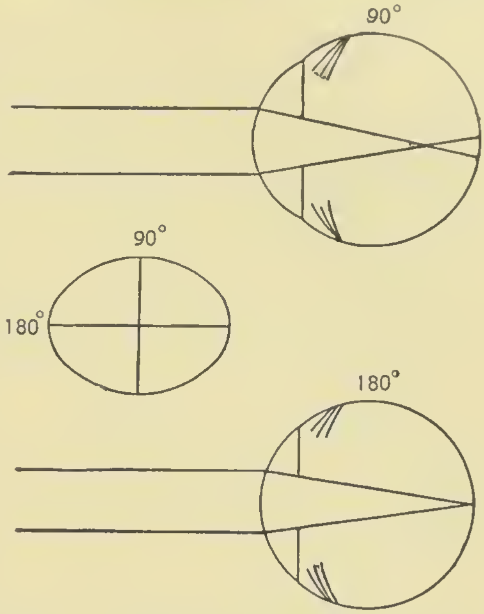


FIG. 61. — Showing myopia of 3 D. in the vertical meridian, and emmetropia in the horizontal meridian.

Their strength was gradually increased up to − 2.50 D., when vision was brought up to $\frac{20}{15}$. No minus spherical glasses were tried in addition to the cylindrical glasses in this case, for the $\frac{20}{15}$ vision, obtained by the patient with simple cylindrical glasses, was proof that no myopia was present in addition to the astigmatism.

CASE XLVIII. *Simple myopic astigmatism with the rule; Some amblyopia; Relief with glasses.* — March 23, 1895. J. H. B., aged eighteen years, in good health, complains of poor vision for distance, and of some difficulty in reading and writing. He has a tendency to half shut his eyes when he tries to see plainly.

Ophthalmometer. — Astigmatism with the rule, 3.50 D., axis 90° + or 180° − in each eye.

Test cards and trial lenses. — The vertical lines on the clock-dial are seen plainest in each eye.

$$\text{R. V.} = \tfrac{20}{70} : \tfrac{20}{40} \text{ W.} - 3 \text{ D. cyl., } 180°.$$

$$\text{L. V.} = \tfrac{20}{70} : \tfrac{20}{40} \text{ W.} - 3 \text{ D. cyl., } 180°.$$

Ophthalmoscope. — Myopia 3 D. at 90° and emmetropia at 180° in each eye.

On a second test the patient accepted the same glasses as at first, and − 3 D. cyl., 180°, was ordered for each eye.

In this case, as vision was not brought to $\frac{20}{20}$ with simple minus cylindrical glasses, I suspected myopia to be present in addition to the astigmatism. I therefore tried minus spherical glasses in addition to the cylindrical glasses, but they did not improve vision any. The ophthalmoscope showed the fundus of each eye to be healthy, so the poor vision was attributed to amblyopia. The simple cylindrical glasses have been worn with comfort for more than three years.

CASE XLIX. *Simple myopic astigmatism with the rule of large amount; Amblyopia, and a mild form of asthenopia.* — July 7, 1892, Frank H., aged eleven years, in good health, complains that he has always seen badly, but has not had much pain in his eyes. He holds his reading matter entirely too close to his eyes, and has to squeeze the lids almost together, in order to see even fairly well. He has never worn a glass.

Ophthalmometer. — Astigmatism with the rule, 4.50 D., axis 105° + or 15° − right eye; 4.50 D., axis 75° + or 165° − left eye.

Test cards and trial lenses. —

$$\text{R. V.} = \tfrac{20}{100} : \tfrac{20}{40} \text{ W.} - 4 \text{ D. cyl., } 15°.$$

$$\text{L. V.} = \tfrac{20}{100} : \tfrac{20}{40} \text{ W.} - 4 \text{ D. cyl., } 165°.$$

Reads Jaeger No. 1 at 10 inches.

Ophthalmoscope. — Myopia 5 D. at 105° and emmetropia at 15° right eye ; myopia 5 D. at 75° and emmetropia at 165° left eye.

As the patient accepted only − 4 D. cylindrical glass, it shows that the estimation with the ophthalmoscope of 5 D. of myopia in the shortest curved meridians was too high by 1 D. The fundus of each eye was normal. There was a scleral ring at the temporal side of each disk.

A second test, three days later, resulted in the patient accepting the same glasses as at the first test, and they were ordered.

Here again, as in Case XLVIII. on account of the amblyopia, vision being brought up to only $\frac{20}{40}$ with simple cylindrical glasses, myopia in addition to the astigmatism was suspected. Minus spherical glasses, therefore, were tried in addition to the cylindrical glasses ; but they did not improve vision any. The somewhat poor vision, $\frac{20}{40}$, was attributed to amblyopia, as the ophthalmoscope showed the fundi to be normal.

Case L. *No corneal astigmatism; Patient accepts − .50 D. cylindrical glasses against the rule; Relief from asthenopia.* — April 24, 1894, James A., aged twenty-three years, in excellent health, has been troubled with his eyes for the last two years. After using the microscope or ophthalmoscope he has pains in the eyes, and if he persists in using his eyes, headaches follow.

Ophthalmometer. — No corneal astigmatism whatever.

Test cards and trial lenses. — The horizontal lines on the clock-dial were seen plainest.

R. V. = $\frac{20}{20}$ −: $\frac{20}{15}$ W. − .50 D. cyl., 90°.

L. V. = $\frac{20}{20}$ −: $\frac{20}{15}$ W. − .50 D. cyl., 90°.

Reads Jaeger No. 1 from 4 to 20 inches.

Ophthalmoscope. — Myopia .50 D. at 180° and emmetropia at 90° in each eye.

A second test resulted in the patient accepting exactly the same glasses as at the first test, and they were ordered, with consequent complete relief of his asthenopia.

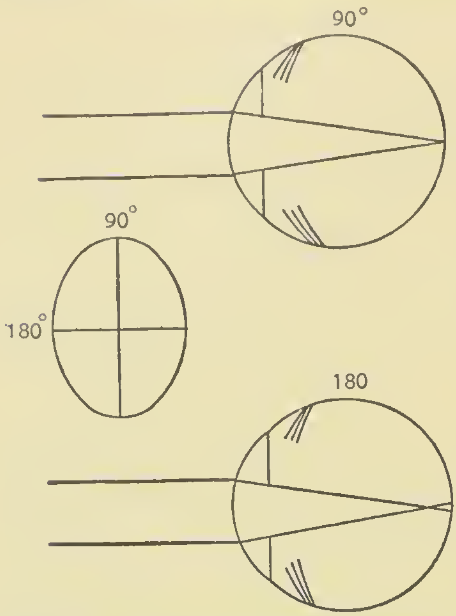


Fig. 62. — Showing myopic astigmatism against the rule — emmetropia in the vertical meridian and myopia in the horizontal meridian.

The retinoscope was used in this case to advantage, as it indicated myopia of a small amount in the horizontal meridian. The lines on the clock-dial were of service also, as they indicated either hypermetropic astigmatism with the rule, or a myopic astigmatism against the rule. Keeping in mind also the fact that, most of the time, when there is no corneal astigmatism, there is usually a small amount of lenticular astigmatism against the rule, I began the test with a plus cylindrical glass, with the axis at 180°. But it made vision worse, so I tried minus cylindrical glasses at 90°. They improved vision, the patient accepting $-.50$ D. cyl., 90°, and getting the best vision.

Case LI. *Simple myopic astigmatism with the rule in the right eye; Lenticular astigmatism against the rule in the left eye, the ophthalmometer showing no corneal astigmatism; Asthenopia; Relief with glasses.* — November 29, 1895, M. L. H., aged twenty-five years, in good health, is a designer of wall papers, which occupation requires very acute vision. The patient complains that for the last two months her eyes have ached and pained her, and also that her head ached if she persisted in using her eyes for an hour or two at her work.

Ophthalmometer. — Astigmatism with the rule, 1 D., axis 90°+ or 180°− right eye; no corneal astigmatism left eye.

Test cards and trial lenses. — The lines on the clock-dial were unsatisfactory.

R. V. = $\frac{20}{40}$: $\frac{20}{20}$ W. – 75 D. cyl., 180°.

L. V. = $\frac{20}{40}$: $\frac{20}{20}$ W. – 50 D. cyl., 90°.

Reads Jaeger No. 1 from 6 to 12 inches.

Ophthalmoscope. — Myopia 1 D. at 90° and emmetropia at 180° right eye; myopia .75 D. at 180° and emmetropia at 90° left eye.

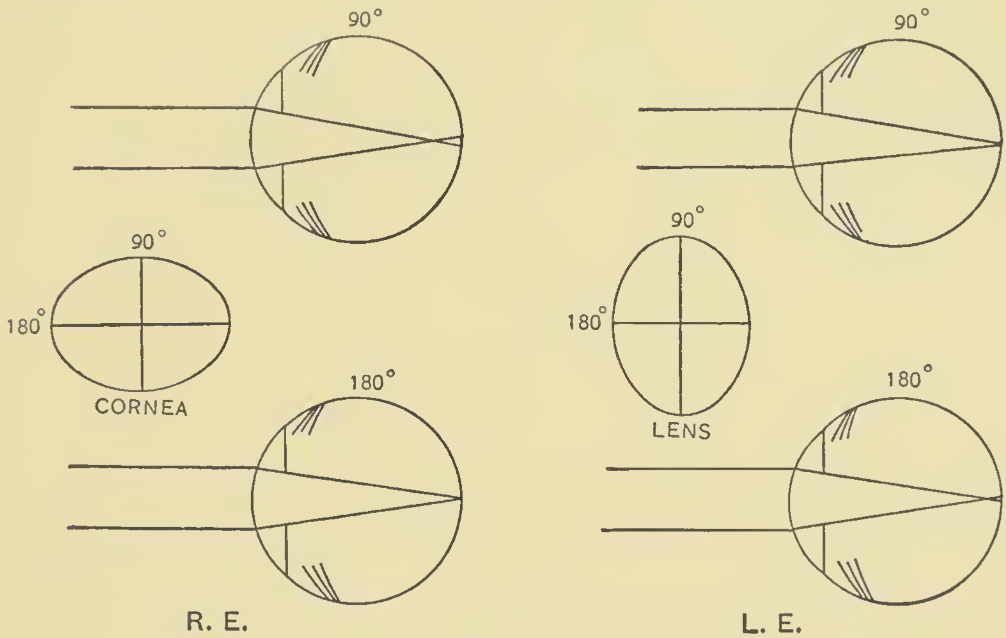


Fig. 63.

The retinoscope confirmed the ophthalmoscopic examination and the subjective test.

A second test was made, and the patient accepting the same glasses as at first, they were ordered. Although one glass is worn at 90° and the other at 180°, they have given her entire relief from her asthenopic symptoms. I have seen the patient frequently since, and she continues to wear the glasses continuously and with comfort.

Case LII. *Simple myopic astigmatism in one eye, and simple myopia in the other; Asthenopia; Relief with glasses.* — May 6,

1896, E. D., aged thirty-two, in good health, but has noticed since boyhood that he could not see quite so well as his companions when looking at distant objects. For the last six months he has experienced pains in the eyes and some frontal headaches after using his eyes for close work for any considerable length of time. Some slight redness of the lids present, also produced by close use of the eyes. He is not of a myopic family, although he has one brother who has myopic astigmatism of small amount. The patient is of the opinion that both he and his brother acquired most of their eye trouble from close application to books, as neither were compelled to wear glasses until near thirty years of age.

Ophthalmometer. — Astigmatism with the rule, 1.25 D., axis 90° + or 180° − right eye; .50 D., axis 90° + or 180° − left eye.

Test cards and trial lenses. —

$$\text{R. V.} = \tfrac{20}{30} - : \tfrac{20}{15} - \text{W.} - .75\ \text{D. cyl. } 180°.$$

$$\text{L. V.} = \tfrac{20}{30} - : \tfrac{20}{15} - \text{W.} - .75\ \text{D.}$$

Reads Jaeger No. 1, $4\frac{1}{2}$ to 20 inches.

Ophthalmoscope. — Myopia 1 D. at 90° and emmetropia at 180° right eye; myopia 1 D. left eye. There is a crescent of choroidal pigment at the temporal side of the disk in the right eye.

Second test: the patient accepted the same glasses as at first, and they were ordered for constant wear. This patient has been under constant observation for more than two years, and the glasses have been worn with entire comfort.

I am of the opinion that had there been no astigmatism in the right eye, but a simple myopia, as in the left eye, no glasses would have been required at all, as .75 D. to 1.50 D. of simple myopia rarely calls for a glass, unless the patient wishes to see very clearly for the distance. Very small amounts of myopic astigmatism, even so little as .25 D., in

exceptional cases when associated with myopia and with slanting axes, may give rise to asthenopia and call for correction, as is shown by one or two cases reported in the following chapter.

CASE LIII. *Corneal astigmatism with the rule, .50 D.; Patient accepts simple spherical glasses of high power for distance, and weaker for reading; The rule for giving two pairs of glasses in high degrees of myopia considered.* — February 26, 1895, I. G., aged thirty-two years, in good health, has had poor vision as long as he can remember, that is, from early childhood. No pain in the eyes or headaches are complained of — simply poor sight.

Ophthalmometer. — Astigmatism with the rule, .50 D., axis 90° + or 180° − in each eye.

Test cards and trial lenses. —

$$\text{R. V.} = \tfrac{4}{200} : \tfrac{20}{50} \text{ W.} - 14 \text{ D.}$$

$$\text{L. V.} = \tfrac{12}{200} : \tfrac{20}{30} \text{ W.} - 11 \text{ D.}$$

Reads Jaeger No. 1 at 8 inches, with − 11 D. right eye and − 8 D. left eye.

Ophthalmoscope. — Myopia 15 D. right eye, myopia 12 D. left eye. Excessive pigmentation (choroidal tigre) in each eye, but no staphyloma in either. Vitreous clear in both.

On a second test, the patient accepted the same glasses, both for the distance and the near point, as at the first test, and they were ordered.

The corneal astigmatism of half diopter in this case was neutralized by the lenticular astigmatism, the usual amount of neutralization, and left it as simple myopia to deal with. This myopia was of so great an amount, however, that two pairs of glasses had to be prescribed, — one for distance and the other for reading, — and not, as it will be noted, on account of presbyopia, for the patient was but thirty-two years of age. This

leads me to deal in a brief manner with the rule of procedure in such cases.

If the myopia is of 8 D. or less, as a rule, the patient will need but one pair of glasses, which can be used both for the distance and the near point. If the patient has worn glasses from early childhood, this one pair is usually sufficient; for, having worn the glasses steadily, and thereby kept the eye corrected, both for far and near work, the ciliary muscle has been developed. On the other hand, in patients who have not come to the use of glasses till later in life (fifteen to twenty years of age), or have worn only partial correction, — say of myopia of 12 D. only 8 D. for the distance, and no correction for the near point, — such patients will not tolerate the distance glass for constant wear. This is because the ciliary muscle has not been developed, the work having been taken from it by the patient taking off his glasses and bringing his work close to him at the focus, *punctum remotum*, of his myopic eye. In this way no accommodative effort is necessary; the ciliary muscle remains passive, and does not develop. In such cases, the reading glasses have to be made weaker, just as in the higher grades of myopia.

In high degrees of myopia, 8 D. or over, my rule of procedure is to find the glasses which give the best distant vision, as in other cases. If the glasses accepted are not higher than 10 or 12 D., and there are no pathological changes in the fundus of the eye of a serious nature, especially if the patient has been wearing nearly his full correction before, I prescribe these glasses for distant vision. In myopia of higher degree than this, the patient will not accept his full correction even for the distance, except for very brief periods at a time. In such cases, the full correction may be prescribed to be used in a lorgnette, while the glasses that are to be worn constantly for the distance must be made weaker. The amount of the reduction depends on the strength of the glasses the patient has previously worn, the age of the patient, and the condition

of the fundus of the eye. Roughly speaking, we would say that a myopia of 14 D. should wear about 12 D. as a constant distance glass; a myope of 16 D. a 14 D.; a myope of 18 D. a 15 D.; and a myope of 20 D. a 16 D. glass, and so on. There are numerous exceptions to this. It is rare to encounter myopia of over 25 D., though cases of as high as 40 D. have been reported at the New York Ophthalmological Society,[1] and without conical cornea.

To get the correct reading glasses in these high degrees of myopia, after having found the glasses I want him to wear constantly for the distance, I divide the number of inches at which the patient wishes to read, or sew, or work, into 40, in order to reduce it to diopters, then subtract the quotient from the distance glasses.[2] The result is the number of the glass that the patient will usually accept for his close work; but a reduction may have to be made in their strength if the patient has not worn glasses for a long time. To give an example, in the last case reported, the patient accepted − 14 D. right and − 11 D. left eye. He wanted a glass to read with comfortably at about

[1] Webster.

[2] Forty is the number of English inches it takes to make a meter, and as my trial lenses are ground after the English inch (also numbered in diopters), I reckon in that system. Whereas, had my trial lenses been numbered after the French system, I would have used 36, the number of French inches it takes to make a meter.

All trial cases were formerly marked in the inch system. For example, a glass of 10-inch focus would be marked $\frac{1}{10}$, one of 40-inch focus, $\frac{1}{40}$, etc. But as confusion was caused by the difference in length of the English and French inches, the dioptric or metric system of numbering was introduced.

In the dioptric system of numbering, the meter is taken as the unit of measure. For example, a glass that will focus parallel rays of light at a distance of one meter is marked one diopter (1 D. thus); a glass that focusses the same rays at half a meter would have to be twice as strong, and is marked 2 D. A glass that focusses rays at two meters' distance would be marked .50 D., or half a diopter. The numbering goes on in an inverse ratio, for the shorter the focus the stronger the glass, necessarily. The metric or dioptric system of numbering is much better than the inch system, for a meter is a meter the world over, while inches of different peoples vary in length from each other.

$\frac{1}{3}$ of a meter, or 13 inches.[1] Forty divided by 13 gave 3 D. in round numbers, which, subtracted from the distance glasses, gave − 11 D. right and − 8 D. left, for his reading glasses, which were prescribed.

Again, say in the above case, the patient wished to read at 10 inches. Divide 40 by 10, which will give 4 D.; subtract this from the distance glasses, and we have − 10 D. right and − 7 D. left, for near work. Or, say the patient wanted to play the piano, or use his eyes for other occupation that would require good vision at a distance of 20 inches; divide 40 by 20, subtract 2 D., the quotient, from the distance glasses, and we would have, in the above case, − 12 D. right and − 9 D. left, for the near work; and so on.

It should be borne in mind here, as, indeed, it should be at all times in fitting glasses, that all eyes are not alike in their working capacity, and will not conform, in exactly the same way, to any set standard or rule. This does not mean that we should not have a rule at all, but that we should have enough intelligence to vary the rule to *suit the case*, and not try to make every case *fit some cast-iron rule.*

In some cases, for the near point, we have to subtract more from the distance glasses than we have indicated here, and in some cases less. The power of convergence has something to do with it; the strength of glasses that the patient has previously worn, the age of the patient, also, all have to be taken into consideration when giving reading glasses to a myope. Indeed, Landolt has laid it down as a general rule, in all degrees of myopia, "that a myope must be prohibited from wearing a concave glass for any distance at which he can see clearly without accommodation."[2] For example, a myope of 2 D. should not

[1] In order to get inches into diopters, divide them into 40 if using the English inch, or into 36 if using the French inch, and *vice versa.* For example (English inch), a 10-inch glass is equal to 4 D., and a 4 D. = 10-inch glass; a 20-inch glass = 2 D., and a 2 D. glass = 20 inches, etc.

[2] Landolt, *The Refraction and Accommodation of the Eye*, p. 490.

have any glass at all for distances under 20 inches, because his *punctum remotum* is at 20 inches, and he can see clearly without them up to that point. I believe it is a good plan myself, however, in all cases of myopia under 8 D., who are compelled to wear glasses for the distance, to keep the glasses on all the time, unless troublesome asthenopia results; then the distance glasses should be weakened according to the rule laid down above; or, if only of moderate strength, 3 or 4 D., taken off altogether for reading unless there is astigmatism present, when only the cylindrical part of the glass should be left on for reading and close work. The reason that I prefer to leave the distance glasses on for near work in such cases is: first, to exercise and develop the ciliary muscle; second, to render the eye emmetropic for all distances, and thus keep up the proper relation between accommodation and convergence; third, because it is less trouble to keep the glasses on all the time than to be taking them off and putting them on frequently. Of course, in very high degrees of myopia, two pairs of glasses have to be resorted to, and sometimes three, if we include the lorgnette which they sometimes use for only a few moments. In cases of high degree of myopia, it is not always, in fact, it is never, simply a question of glasses, especially where progressive or malignant myopia is to be dealt with. In such cases, a general hygienic régime has to be followed, so far as the eyes are concerned, and the constitution built up with tonics. All close work with the eyes must be prohibited, shaded glasses worn, local blood-letting practiced, the patient made to exercise and take the proper amount of rest, and so forth. In fact, the general condition of the patient should be brought up to the best. Unfortunately, such cases often occur in childhood, when the patient is trying to pursue his studies. It is unnecessary to say that such patients must be taken out of school, because close application to books always makes the myopia worse.

In cases of high degrees of myopia, not malignant in char-

acter, that is, with healthy fundi, or, at most, with only a slight posterior staphyloma, and with but little tendency to increase, it is well for the patients to use the eyes as little as possible, and only with good light. In order to prevent straining the eyes, these patients often acquire the practice of using but one eye at a time, especially for near work, pulling off the glasses and bringing the print up to the focus (*punctum remotum*) of the eye he uses. In this way he uses no accommodation, and, at the same time, the images are much larger for the eye without the strong myopic glasses, which always make objects look much smaller. The eye that is not used usually swings out, that is, diverges. Where the eyes are sound, however, I always encourage the use of glasses, and, in that way, give the stimulus to binocular vision both for the distance and for the near point. A divergent squint is sometimes prevented in this way, just in the same way as a convergent squint is sometimes prevented, and even cured in young children after once having appeared, by wearing plus glasses.

The following case of moderate degree of myopia in one eye, and only a small amount in the other, with a tendency to, and, at times actual, squint outward, is a case in point.

Case LIV. *Myopia of moderate amount in one eye and small amount in the other; Occasional divergent squint; Asthenopia; Relief of the squint and asthenopia with correcting glasses.* — January 4, 1898, Miss E. M. L., aged twenty-one years, in good health, has been near-sighted in the right eye since a child, her family have noticed at times, when she was looking in the distance, that the right eye would turn outward. With close attention, however, the eye would turn back, and not squint. When she reads at night, the eyes tire, but there is little pain in them, and she rarely has headaches.

The ophthalmometer showed a small amount of corneal astigmatism in each eye; and, on the first test, the patient

accepted compound glasses, but, on the second test, simple myopic spherical glasses gave the best vision.

Ophthalmometer. — Astigmatism with the rule, .75 D., axis 75°+ or 165°− right eye; .25 D., 90°+ or 180°− left eye.

Test cards and trial lenses. —

$$\text{R. V.} = \tfrac{20}{200} : \tfrac{20}{20} - \text{W.} - 4.50 \text{ D.} - .50 \text{ D. cyl., } 165°.$$

$$\text{L. V} = \tfrac{20}{20} - : \tfrac{20}{20} \text{ W.} - .25 \text{ D.} - .25 \text{ D. cyl., } 180°.$$

Reads Jaeger No. 1, 3 to 12 inches right eye, and from 5 to 25 inches in the left eye. Unless she looks at the point attentively, the right eye turns outward for the near point; also, when looking in the distance, unless she is attentive, the right eye swings outward.

Ophthalmoscope. — Myopia 5 D. right eye; myopia 1 D.(?) left eye; normal fundi.

On account of a mild conjunctivitis, alum was applied to the lids, an astringent wash prescribed, and the patient directed to come again in a week for a second test. This seemed advisable, because there were unmistakable signs of spasm of accommodation during the subjective test. The retinoscopic test was unsatisfactory.

Second test: the ophthalmometer gave the same reading as at the first test.

$$\text{R. V.} = \tfrac{20}{200} : \tfrac{20}{20} \quad \text{W.} - 5 \quad \text{D.}$$

$$\text{L. V.} = \tfrac{20}{20} : \tfrac{20}{20} + \text{W.} - .50 \text{ D.}$$

The ophthalmoscope and retinoscope both confirmed the subjective test. The tendency to spasm of accommodation had subsided. I ordered for constant wear −4.50 D. right and a plain glass left. The patient has been under observation for a period of eight months. She has single binocular vision both for near and far with the glasses, is entirely free from asthenopia, and is much pleased with the result.

Case LV. *Myopic astigmatism of moderate amount; Presbyopia; Simple minus cylindrical glasses for the distance, and cross-cylindrical glasses for reading.* — May 28, 1897, L. J., aged forty-five years, in good health, has worn glasses since nineteen years of age, which are all right for the street now, but have not been comfortable for reading purposes for the last two or three years. Her distance glasses are – 2. D. cyl., 180°, in each eye.

Ophthalmometer. — Astigmatism with the rule, 2.50 D., axis 90° + 180° – in each eye.

Test cards and trial lenses. —

$$\text{R. V.} = \tfrac{20}{30} - : \tfrac{20}{20} \text{ W.} - 2\text{ D. cyl., } 180°.$$

$$\text{L. V.} = \tfrac{20}{30} - : \tfrac{20}{20} \text{ W.} - 2\text{ D. cyl., } 180°.$$

Reads Jaeger No. 1 from 7 to 18 inches, with + 1 D. spherical glass added to the distance glasses.

Ophthalmoscope. — M. 2 D. in the vertical meridian, and emmetropia in the horizontal meridian in each eye.

The patient was allowed to continue the minus cylindrical glasses for distant vision, and + 1 D. – 2 D. cyl., 180°, was ordered for each eye for reading purposes. This glass in effect is the same as cross-cylinders, that is, + 1 D. cyl., 90° – 1 D. cyl., 180°. But, before going into details of the transposition of glasses that is made necessary in cases of myopes who have become presbyopic, I wish to report two other cases of simple myopic astigmatism in presbyopes, in order to have two or three cases for illustration, rather than one.

Case LVI. *Simple myopic astigmatism with the rule; Presbyopia; Minus cylindrical glasses for the distance, and plus cylindrical glasses for the near work.* — August 16, 1896, Samuel T., aged forty-six, in good health, has worn glasses since twenty years of age, on account of near-sightedness. For the past

two years he has experienced some trouble in his near work, especially when reading at night.

Ophthalmometer. — Astigmatism with the rule, 1.50 D., axis 90° + or 180° – in each eye.

Test cards and trial lenses. —

R. V. = $\frac{20}{30}$: $\frac{20}{15}$ W. – 1 D. cyl., 180°.

L. V. = $\frac{20}{30}$: $\frac{20}{15}$ W. – 1 D. cyl., 180°.

Reads Jaeger No. 1 from 8 to 20 inches, with +1 D. sphere added to the cylindrical glasses.

Ophthalmoscope. — M. 1 D. in the vertical meridian (90°), and emmetropia in the horizontal meridian (180°) in each eye.

The patient is now wearing –1 D. cyl., 180°, exactly the same glasses he accepted in this test, and they were ordered continued. For reading glasses +1 D. cyl., 90°, was ordered for each eye.

CASE LVII. *Simple myopic astigmatism with the rule in one eye and against the rule in the other; Presbyopia; Minus cylindrical glasses for the distance and plus cylindrical glasses for reading.* — October 10, 1896, Kate M., aged forty-one, in good general health, for the last year her eyes have given her a great deal of trouble for close work. The vision blurs, and the eyes and head ache after using the eyes.

Ophthalmometer. — Astigmatism with the rule, 1 D., axis 60° + or 150° – right eye; astigmatism against the rule, 1 D., 135° + or 45° – left eye.

Test cards and trial lenses. —

R. V. = $\frac{20}{30}$: $\frac{20}{20}$ W. – .50 D. cyl., 15°.

L. V. = $\frac{20}{30}$: $\frac{20}{20}$ W. – .50 D. cyl., 45°.

Reads Jaeger No. 1 at 8 inches, with +.50 D. added to the distance glasses.

Ophthalmoscope. — M. 1 D. at 60° and Em. at 150° right eye; M. 1 D. at 135° and Em. at 45° left eye.

On a second test, this patient accepted the same glasses, both the distance and the near, as at the first test. As her eyes gave her no special trouble for the distant vision, I prescribed only the reading glasses, +.50 D. cyl., 60° right, and +.50 D. cyl., 135° left.

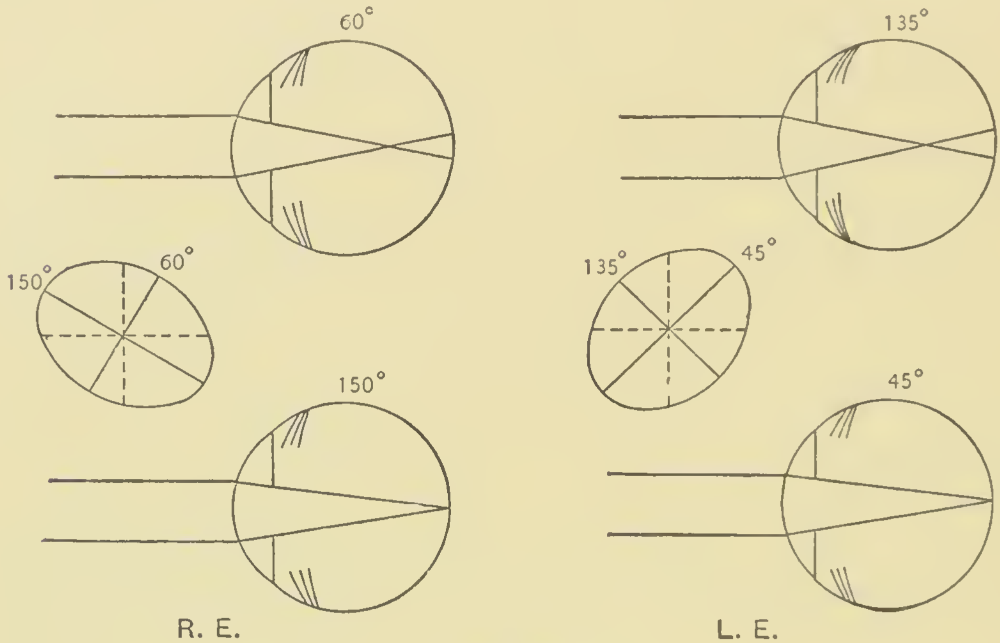


Fig. 64.

It will be noticed in this case that although the instrument reads astigmatism against the rule, 1 D., in the left eye, the patient accepts only .50 D. cyl., the same amount as the other eye, wherein the instrument reads astigmatism with the rule, 1 D. This makes me repeat what I have already pointed out above, that when the chief meridians are exactly at 45° and 135°, as in the left eye in this case, the terms "with the rule" and "against the rule" do not strictly hold. This should be borne in mind, therefore.

Presbyopic Glasses for Myopes

For the benefit of students and beginners in the practice of ophthalmology, I think it well at this place to consider briefly the influence of presbyopia as it affects the reading glasses,

especially in myopes. It is, as a rule, an easy matter to give the correct reading glasses to an emmetropic, or a hypermetropic individual. To do so it is necessary only to add a certain increase to the distance glass (if the patient accepts any distance glass), usually about + 1 D. spherical glass for each five years of age after forty years of age, to get the correct glasses. A better standard, perhaps, is the one of giving the glasses that the patient can read with, with comfort, at 13 inches, or with effort at 8 inches. As stated above, this requires about + 1 D. for each five years after forty years of age; but some patients will accept but .50 D., while others will require as much as 1.50 D., or even more in exceptional cases, for each five years after forty years of age, in order to read with comfort (Jaeger No. 1) at 13 inches, or with effort at 8 inches. For instance, to give an example or two, an emmetrope at forty-five years of age should wear about + 1 D. for reading, and at fifty years of age + 2 D., and at fifty-five years + 3 D., and so on. The variation from this is easily ascertained by having the patient read the Jaeger No. 1 type at 8 inches. The glass that is required to enable him to read this type at that distance, with effort, is the correct glass (Donders).

Again, a hypermetrope who is wearing + 2 D. for the distance should wear about + 3 D. for reading when forty-five years of age, and + 4 D. at fifty years, etc. Or if the patient is wearing compound hypermetropic glasses for the distance, it is only necessary to add to the spherical part of the glass the usual amount of + 1 D. for each five years, in order to get the correct reading glasses, leaving the cylindrical part as it is.

In myopic astigmatism the fitting of presbyopic glasses is not so easy, especially for the beginner; for the changing from minus cylindrical glasses to plus, with change of axis, though apparently very simple by the algebraic equation, is not, as a rule, quickly grasped by the student. For this reason I not

only teach them the method by algebraic equation, but draw diagrams of the eye showing the focus of the two chief meridians for the distance, and then the change of focus brought about by presbyopia, calculating on the basis of + 1 D.[1] for each five years. This places before the eye of the student the change of focus of each meridian, and at the same time indicates the nature and strength of the glass necessary for the near work of the patient. It has the further advantage of making the student think of the eye under observation, and does not let him decide the matter by an abstract algebraic equation. This may seem of little importance to those who do not instruct; but, I am sure, to teachers, this concrete way (with the assistance of diagrams) of imparting knowledge will at once be apparent as the better method of teaching.

Now, in simple myopia without astigmatism, the fitting of presbyopic glasses is not difficult, because, adding + 1 D. (algebraically) for each five years of age after forty to the distance glass, we easily get the right glass for reading or working purposes. To take an example, say the patient wears − 2 D. for distant vision, and is forty-five years of age. Add + 1 D. to − 2 D., and we have left − 1 D., which would be the reading glass. At fifty years of age the patient would be 2 D. presbyopic. Plus 2 D. added to − 2 D. equals 0, that is, they exactly neutralize, so that the patient would need no reading glass at this age. At fifty-five years of age, + 3 D. added to − 2 D. would give + 1 D., which would be the correct glass.

In cases of simple myopia of high degree, where two pairs of glasses are worn, in giving presbyopic glasses, we add the presbyopic glass to his weaker glasses (the glasses that he uses for near work), and leave the distance glass as it is. Nevertheless, even this distance glass of high myopes has to be weakened as the patient advances in age; for even the *static*

[1] Of course the 8-inch test for Jaeger No. 1 is the final decisive test.

refraction of the eye begins to get weaker at fifty years of age, and at eighty years of age has actually decreased about 2.50 D. In Case LIII, for instance, where – 14 D. right and – 11 D. left were ordered for the distance glass, and –11 D. right and – 8 D. left for reading, when this patient reaches forty-five years of age he should wear, on account of his 1 D. of presbyopia, + 1 D. added to – 11 D. right, and + 1 D. added to – 8 D. left, which would give for reading glasses – 10 D. right and – 7 D. left. At fifty years of age, + 2 D. added to – 11 D. and – 8 D. would give – 9 D and – 6 D., respectively, as the reading glass, and so on.

On account of the decrease of the *static* refraction of the eye, his strong distance glasses, – 14 D. right and – 11 D. left, should be decreased in strength, and much more than is indicated by the tables of scales as given in the various text-books. At the age of sixty, for instance, the static refraction has decreased .50 D., yet a much greater reduction in the strength of the distance glasses has to be made than this amount where the myopia is of high degree.

In myopic astigmatism in presbyopes we have to deal with the transposition of cylindrical glasses, and it is not so easy as in cases of simple myopia and spherical glasses.

I will take some of the cases reported in this chapter as illustrative examples. In Case LVI, the patient accepted for the distance – 1 D. cylindrical glass, axis 180°, in each eye. He was forty-six years of age, and required a reading glass. He accepted + 1 D. cyl., 90°, in each. A + 1 D. spherical glass added to – 1 D. cyl., 180°, would be in effect + 1 D. cyl., 90°. As the latter glass was simpler, lighter, and cheaper, it was prescribed. A glance at Fig. 65 will show the change in focus brought about by the 1 D. of presbyopia.

The 1 D. of myopia in the vertical meridian is just neutralized by the 1 D. of presbyopia; while the horizontal meridian, which was emmetropic, becomes in effect hypermetropic 1 D.,

by reason of the 1 D. of presbyopia. In other words, the eye for reading purposes at that age is converted into a simple hypermetropic, astigmatic eye, and requires a simple + 1 D. cyl., 90°, to correct same.

At fifty years of age the patient would require for a reading glass + 1 D.s + 1 D. cyl., 90°; for, on account of 2 D. of presbyopia, the focus in the vertical meridian, for reading purposes, has receded behind the retina, as well as the focus in the horizontal meridian (in the vertical meridian 1 D. and in

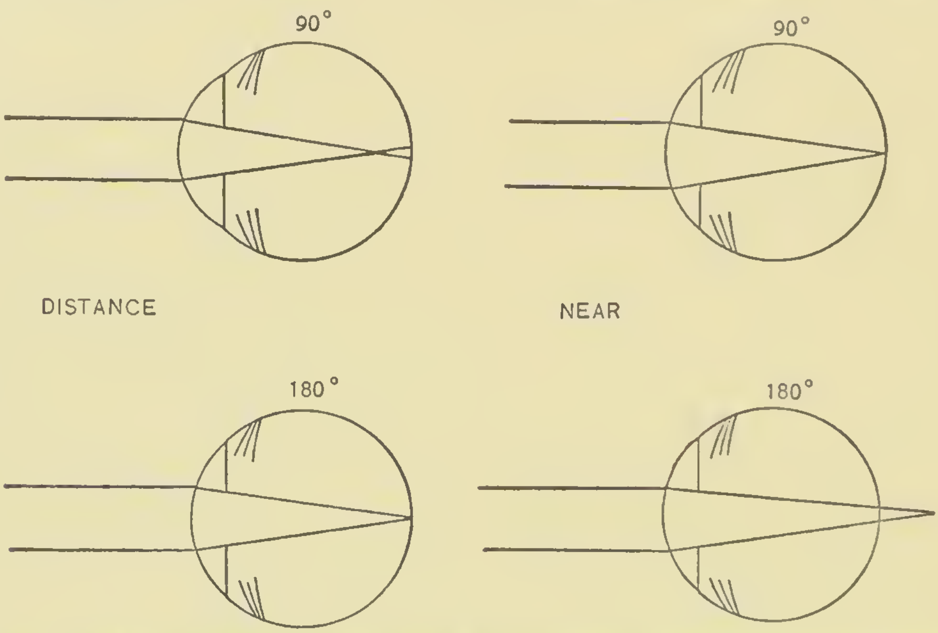


FIG. 65.—Showing focuses of chief meridians for distant vision and for near vision at the age of forty-five years, in simple myopic astigmatism of 1 D.

the horizontal meridian 2 D.). A + 1 D. sphere corrects the vertical meridian and half the presbyopia of the horizontal meridian, the + 1 D. cyl., 90°, being required to complete the correction in the horizontal meridian.

At fifty-five years of age, this patient would require + 2 D.s + 1 D. cyl., 90°, and so on, about + 1 D. spherical glass extra for each five years being required to be added to the cylindrical glass.

Take another example, suppose the patient accepts − 2 D. cyl., axis 180°, for the distance, as in Case LV. At forty-five

years of age, this patient would be about 1 D. presbyopic, and should wear for reading + 1 D. – 2 D. cyl., 180°, in each eye; or, if we chose, we could give cross-cylinders, *e.g.*, +1 D. cyl., 90° – 1 D. cyl., 180°, which glass is exactly the same in effect as the sphero-cylindrical glass + 1 D. – 2 D. cyl., 180°.

To make this perfectly plain, we will give a diagram of the eye, showing, first, the foci of the two chief meridians for distant vision; and, second, the foci as affected by the 1 D. of presbyopia at forty-five years of age.

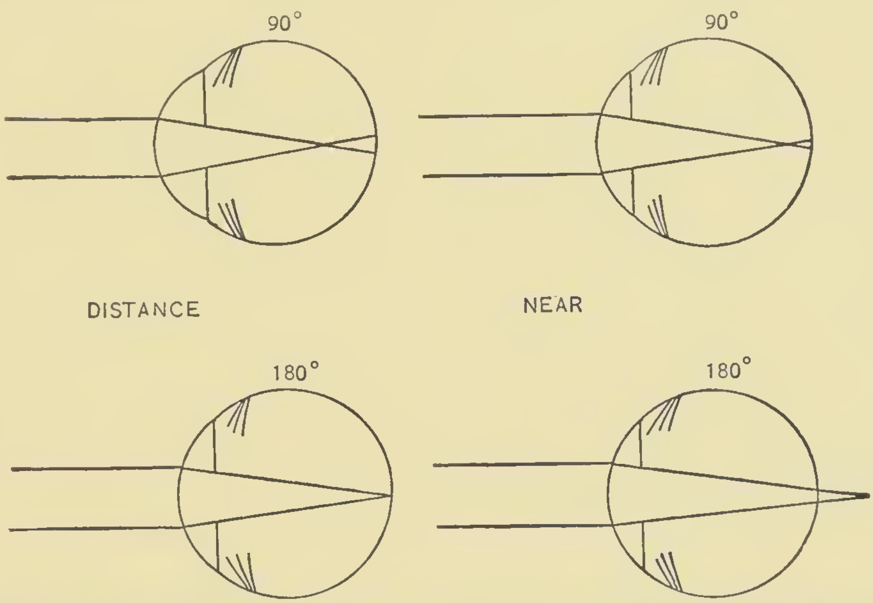


FIG. 66.—Showing focuses of the chief meridians in simple myopic astigmatism of 2 D. for distant vision and for near vision at the age of forty-five years.

The 1 D. of presbyopia neutralizes 1 D. of the myopic astigmatism in the vertical meridian (leaving 1 D. of it uncorrected), and at the same time renders the horizontal meridian (which is emmetropic) presbyopic, or in effect hypermetropic 1 D. Thus the eye for reading purposes is mixed astigmatic, since it focusses rays of light in front of the retina in the vertical meridian, and back of the retina in the horizontal meridian. Now, to correct this we can give either the cross-cylindrical glasses, + 1 D. cyl., 90° – 1 D. cyl., 180°; or we can give sphero-cylindrical glasses, + 1 D. – 2 D. cyl., 180°. In the

first instance, with the cross-cylinders, the + 1 D. cyl., 90°, corrects the 1 D. of presbyopia in the horizontal meridian, and the − 1 D. cyl., 180°, corrects the one remaining diopter of myopic astigmatism in the vertical meridian. In the second instance, with the sphero-cylindrical glasses, the + 1 D. sphere corrects the 1 D. of presbyopia in the horizontal meridian, and at the same time renders the eye myopic to that extent in the vertical meridian; and the increase of myopic astigmatism by 1 D. in addition to the 1 D. already present makes it necessary to give − 2 D. cyl., 180°, instead of − 1 D. cyl., as when cross-cylinders were prescribed. In other words, we have to neutralize the effect of the plus spherical glass in the vertical meridian. This, of course, makes a heavier glass than a cross-cylindrical. The field of vision also is made somewhat smaller by the sphero-cylindrical glasses than by the cross-cylindrical. But both of these objections are of but little importance in mixed astigmatism of low degree, as in the present instance. When the mixed astigmatism is of large amount, cross-cylindrical glasses are to be given in preference to sphero-cylindrical, as a general rule.

At fifty years of age, this patient (Case LV) would require a simple + 2 cyl. axis 90°, because at this age the 2 D. of myopic astigmatism in the vertical meridian is just neutralized by the 2 D. of presbyopia, while the emmetropic horizontal meridian is rendered 2 D. presbyopic (or hypermetropic in effect), and requires the + 2 D. cyl., 90°, to correct same. At fifty-five years of age, the patient would wear + 1 D. + 2 D. cyl., 90°; and at sixty years, + 2 D. + 2 D. cyl., 90°, and so on.

For the transposition of glasses, made necessary on account of presbyopia, in compound myopic astigmatism, and in mixed astigmatism, suitable examples are given for illustration in the chapters on compound myopic astigmatism and mixed astigmatism, which immediately follow.

CHAPTER VI

COMPOUND MYOPIC ASTIGMATISM — ANTIMETROPIA — ILLUSTRATIVE CASES — ACCESSORY EFFECTS OF STRONG MYOPIC GLASSES

In testing for glasses in compound myopic astigmatism, we begin the test in exactly the same way as when testing for the glasses in simple myopic astigmatism. That is, we examine the eye first with the ophthalmometer to ascertain if there is any corneal astigmatism. Having found the amount and axis of the astigmatism, we next begin the subjective test with the trial case and test card. And here, and as a matter of fact in all errors of refraction where astigmatism is present, we begin the test with weak plus cylindrical glasses, unless we know beforehand the nature of the error of refraction; for the examination with the ophthalmometer does not reveal the nature of the error of refraction, and plus glasses are begun with in order to avoid inciting a spasm of accommodation.[1] If the patient proves not to be hypermetropic, no harm is done and but little time lost. We then begin with weak minus cylindrical glasses at the axis indicated by the ophthalmometer, and gradually increase their strength so long as they improve vision, being careful to stop with the weakest glass that gives the best vision. If the vision is not brought up to perfect, $\frac{20}{20}$, with cylindrical glasses alone, we next add a weak minus spherical glass to the cylinder, and if it improves vision, gradually increase it in strength until the vision ceases to be improved. The weakest minus glasses that give the best vision are given.

[1] As explained in a previous chapter, if minus glasses are begun with they are often accepted, though the patient be hypermetropic.

In very high degrees of myopia complicated with astigmatism, especially where the astigmatism is of small or only moderate amount, we have to correct part or most of the myopia before the cylindrical glass is appreciated when placed in front of the eye. Starting the test in the routine way in such cases, plus glasses would of course make the vision worse, and would be refused; and minus cylindrical glasses, though accepted, would not appreciably improve vision. Notwithstanding the fact that the cylindrical glasses, as indicated by the ophthalmometer, do not appreciably affect the vision one way or the other, I leave them in the trial frames and add minus spherical glasses to them, rapidly increasing them in strength. If the poor vision is due to myopia, and no very serious fundus changes have taken place to cause amblyopia, the minus spherical glasses, which give the best vision, are soon found. When I have reached this point in the test, I then leave the minus spherical glasses in the trial frames and go back to the cylindrical glasses, increasing and diminishing them in strength alternately, to see if vision can be further improved; for, with the myopia corrected, any change in the cylindrical glasses is more easily perceived. However, as above stated, where the myopia is large in amount, 8 D. or more, and the astigmatism small in amount, cylindrical glasses increase the vision very little when added to the spherical glasses, at times even when the astigmatism is as much as 2 D. In such cases, and particularly when the astigmatism is with the rule and exactly at 180°, it is often best to give simple spherical glasses alone, tilting them slightly on the horizontal axis, the upper part forward, to get the necessary cylindrical effect. The patient will do this tilting for himself, if it is not done for him, after wearing them for a few weeks.

The giving of a simple spherical glass and tilting it on the horizontal axis is, when it can be done, advantageous in three ways: first, it is a simple glass, and not a compound one;

second, it is a lighter glass; and third, it is a cheaper glass than a compound one.

We are to be guided in such instances (giving only spherical glasses where there is a large amount of myopia and only a small amount of astigmatism) by the increase of vision the cylindrical glass gives when added to the spherical glass. For example, say a patient accepts a – 10 D. spherical glass and his vision is brought up to $\frac{20}{30}$ with it; and by adding a – .75 D. cyl., axis 180°, the vision is increased to only $\frac{20}{20}$ –, or not one whole line. In such case I would not give the compound glasses, but the simple – 10 D., and tilt them slightly forward on the horizontal axis.

Where the myopia is not large in amount (under 8 D.), and the astigmatism is moderate or small in amount, and when the vision is considerably improved by the correction of this astigmatism, it is best to give a compound glass. This is the more important if the axis of the astigmatism is off from 180°, for then it is difficult to get the proper cylindrical effect by tilting the spherical glasses.

Where there are fundus complications, vision will not, as a rule, be improved much with any glass whatsoever. Moreover, if the myopia is of the progressive type, glasses are of secondary importance; for, in such cases, constitutional treatment and general hygienic conditions are much more to be considered. The eyes should be given complete rest, and, if sensitive to light, shaded glasses should be worn. In cases of children with progressive myopia, they should be taken from school, or be allowed to go for only one or two hours a day; for, if close application at books is persisted in, the eyes are irreparably injured by hastening the progress of the disease.

CASE LVIII. *A typical case of compound myopic astigmatism; Slight asthenopia; Vision brought up to perfect, $\frac{20}{20}$, with glasses.* — April 4, 1897, C. A. B., aged twenty-seven years, consulted me four months ago on account of a chalazion on the

right upper eyelid, which was cured by incising and curetting. He comes now on account of poor vision, and for slight pain in the eyes, after using them for continuous close work. His vision has never been very good, and, until lately, he has been free from asthenopia.

Ophthalmometer. — Astigmatism with the rule, 2.50 D., axis 90°+ or 180°− in each eye.

Test cards and trial lenses. — The vertical lines on the clock-dial are seen plainest, though none of them are seen very plain.

R. V. = $\frac{10}{200}$: $\frac{20}{20}$ + W. − 3.50 D. − 2.50 D. cyl., 180°.

L. V. = $\frac{10}{200}$: $\frac{20}{20}$ + W. − 3.50 D. − 2.50 D. cyl., 180°.

Reads Jaeger No. 1 from 4 to 20 inches.

Ophthalmoscope. — M. 5 D. in the vertical meridian (90°), and M. 3 D. in the horizontal meridian (180°), in each eye. The fundus in each eye is normal.

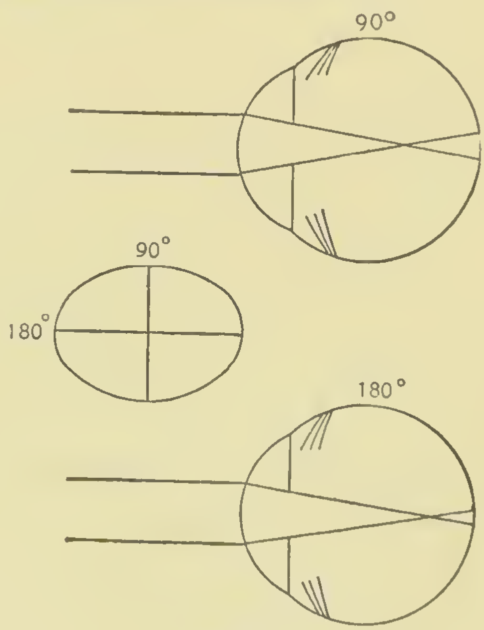


Fig. 67.

Five days later a second test was made. The ophthalmoscope and ophthalmometer showed the same condition as at the first test.

Test cards and trial lenses. —

R. V. = $\frac{10}{200}$: $\frac{20}{20}$ + W. – 3 D. – 2.25 D. cyl., 180°.

L. V. = $\frac{10}{200}$: $\frac{20}{20}$ + W. – 3 D. – 2.25 D. cyl., 180°.

This last glass was ordered. It has given relief from his asthenopia, and is worn with great satisfaction and comfort. I may say that my routine method was followed in testing this case. Plus cylindrical glasses were first tried; these were rejected. Then minus cylindrical glasses were tried, and the patient accepted a – 2.25 D. cyl., 180°, with improvement in vision; but, as it was not brought up to normal vision, minus spherical glasses were added to the cylindrical, the strength being gradually increased till – 3 D. was reached. As this combination of glasses was the weakest minus glass that gave him the best vision, it was ordered.

The same routine procedure was pursued in all of the following cases.

CASE LIX. *Compound myopic astigmatism, where the myopia is considerable in amount and the astigmatism small in amount; Patient is wearing spherical glasses; Slight asthenopia, with poor vision; Relief with glasses.* — February 7, 1895, Annie C., aged twenty-eight years, in good general health, consulted me on account of poor vision and occasional headaches over the brows. She comes of a myopic family. She fitted herself to glasses sometime ago (– 5 D. sphere each eye), but they have not given relief.

Ophthalmometer. — Astigmatism with the rule, 2 D., axis 80°+ or 170°– right eye; 2 D., axis 100°+ or 10°– left eye.

Test cards and trial lenses. —

R. V. = $\frac{6}{200}$: $\frac{20}{30}$ W. – 5 D. – 1.50 D. cyl., 170°.

L. V. = $\frac{4}{200}$: $\frac{20}{30}$ W. – 5 D. – 1.50 D. cyl., 10°.

Reads Jaeger No. 1, 5 to 15 inches.

Ophthalmoscope. — M. 7 D. at 80° and 5 D. at 170° right eye; M. 7 D. at 100° and 5 D. at 10° left eye.

There is a narrow crescentic staphyloma to the temporal side of the disk in each eye.

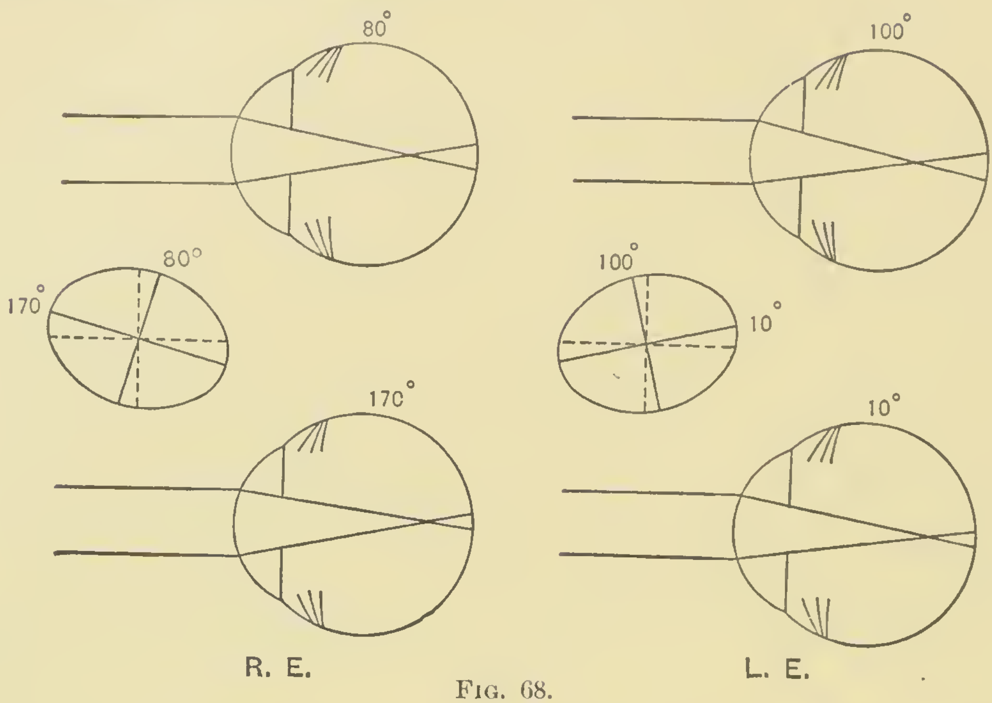


FIG. 68.

On a second test the patient accepted the same glasses as at first; they were ordered, and have given satisfaction for more than three years.

CASE LX. *Compound myopic astigmatism, the myopia being large in amount, while the astigmatism is small in amount.* — June 15, 1894, Miss E. E. D., in fairly good health only, consulted me on account of poor vision. There is no asthenopia. She comes from a myopic family, and her sight has been poor from childhood.

Ophthalmometer. — Astigmatism with the rule, 2.25 D., axis 100°+ or 10°− right eye; 2.25 D., axis 75°+ or 165°− left eye.

Test cards and trial lenses. —

R. V. = $\frac{4}{200}$: $\frac{20}{70}$ W. − 16 D. − 1.25 D. cyl., 10°.

L. V. = $\frac{4}{200}$: $\frac{20}{70}$ W. − 16 D. − 1.25 D. cyl., 165°.

Reads Jaeger No. 1 at 7 inches, with − 10 D. spherical glass on each eye.

Ophthalmoscope. — Myopia of 16 D. in each eye. There is a large posterior staphyloma in each, but there is little choroidal change.

A second test resulted in the patient accepting the same glass as at first ; ordered, – 16 D. for the distance, in the form of a hand-lorgnette, and – 10 D. for close work.

In this case the myopia was so great and the amblyopia so marked that the cylindrical glass improved vision but little, so it was not added to the spherical glass, especially as the latter was already very heavy. Moreover, it many times happens, in these cases of high degree of myopia, that the patient is not able to wear the full correction, even in the street. In such instances we must reduce the power of the glass if we give it for constant wear ; or give it full strength in a lorgnette, to be used for only a few moments at a time, when the patient wishes to see distinctly.

Patients who have worn glasses from childhood can wear much nearer their full correction, in these high degrees of myopia, than those who have worn very weak glasses, or none at all till later in years. The reasons for this are : first, in those who wore glasses that corrected most of their myopia from early childhood, the ciliary muscle had to be used when looking close at hand, and in this way it was developed ; and strong glasses can on this account be worn without fatigue. But in those who have not worn anything like their full correction, or have worn no glass at all, the ciliary muscle remains undeveloped from non-use ; and when strong glasses are prescribed, requiring the use of the ciliary muscle for near work, the eyes easily tire, because of the very weak ciliary muscle. Second, the distorting and minifying effects of strong myopic glasses are not noticed so much by a child in early life, and he grows accustomed to the effects as natural ones ; while the effects of such glasses prescribed later in life are very annoying, so much so, that in some cases patients will not tolerate

anything like the full correction. The prismatic action and minifying action of strong minus glasses have to be taken into consideration, and a reduction in the strength of the glass has to be made to secure comfort for the patient. I have in mind one patient who accepted − 17 D. and saw $\frac{20}{30}$ on Snellen test cards with the same, yet was unable to, or rather would not, wear them on the street, because, as she said, she could not recognize her intimate friends in the street with them on, on account of the distortion and contraction of their features. She had been wearing − 10 D. before, and − 12 D. was the strongest she could wear with comfort, though she saw much worse with this than with the − 17 D., so far as the test cards were concerned. In these very high degrees of myopia, therefore, there is no strict rule by which we may go, and we have to seek the comfort of the patient. I usually reduce the glass from the full correction, even for street wear, and give a still weaker glass for reading. If the patient desires a full correction, I give it in a lorgnette, which can be used for a few moments at a time.

I have prescribed as high as − 22 D., on one occasion, for a man who had about 26 D. of myopia. He had only one eye, however, and the troublesome question of the relation between convergence and accommodation was eliminated in his case. Not only did this glass minify objects in a marked degree, but when his eye was looked at through the glass, it made the eye appear very small to the observer, in fact, almost like a bead.

There is another point about cases of high degree of myopia, especially where there are fundus lesions, that I wish to call attention to here, and that is, that their vision seems much worse when the stomach is upset or their general condition much disturbed in any way. After they have quieted down, the vision comes up to what it was before the disturbance occurred and they are again happy, though much concerned about their sight at the time of the disturbance. If this point

is not borne in mind, we might be induced by the patient to change the glasses unnecessarily at such time.

The general health of these patients should be looked after most carefully, outdoor exercise ordered, rest to the eyes enjoined, and close work for the eye for any considerable time prohibited. In school children especially, who show any tendency to progressive or malignant myopia, too much stress cannot be laid on the observance of general hygienic conditions, such as much out-of-door exercises, short hours of study, — and then under the most favorable surroundings, — good light, upright position of the child at desk, etc., and proper correction of errors of refraction. It is much better to let these children go through school with a little book learning, rather than to let them acquire knowledge, at the expense of eyesight, which they can never put into effect in after life. In fact, if it comes to a question of school education or eyesight, stop the child from school altogether; at any rate, allow him the fewest of hours of study possible, and this time to be divided by short intervals, so as not to weary the eyes too much.

Case LXI. *Large amount of myopia with a moderate amount of astigmatism with the rule; Axis of the astigmatism horizontal in one eye and off from the horizontal in the other; Asthenopia; Relief with glasses.* — June 1, 1896, Katie McQ., aged thirty-one years, in good health, comes on account of poor vision and some asthenopic symptoms. She is now wearing -9.50 D.s right eye and -9 D.s left eye.

Ophthalmometer. — Astigmatism with the rule, 3 D., axis 105° + or 15° − right eye; 1.50 D., axis 90° + or 180° − left eye.

Test cards and trial lenses. —

$$\text{R. V.} = \tfrac{20}{200} : \tfrac{20}{70} \text{ W.} - 8 \text{ D.} - 2.50 \text{ D. cyl., } 15°.$$

$$\text{L. V.} = \tfrac{4}{200} : \tfrac{20}{70} \text{ W.} - 11 \text{ D.} - 1 \text{ D. cyl., } 180°.$$

Reads Jaeger No. 1 at 9 inches.

Ophthalmoscope. — M. 11 D. at 105° and 8 D. at 15° right eye; M. 13 D. left eye. There is a small posterior staphyloma in the right eye, and a large one in the left, with spots of choroidal changes scattered over the fundus in each.

Second test: the patient accepted the same glasses as at the first test, and these were ordered.

In this case the vision was considerably improved by the addition of the cylindrical to the spherical glasses, and the full correction was ordered to be worn constantly, although the myopia was large in amount in the left eye. The glasses were worn with perfect comfort.

I wish to emphasize a point in this case which has already been alluded to in this chapter in a general way, and that is, that the patient was able to wear these strong myopic glasses for near work with comfort. This is not always so, and in her case was due to the fact that she had worn almost full correction for her myopia since a child; and, having her myopia corrected for the distance, she was compelled to use her accommodation for near points. In this way the ciliary muscle was developed, and when she came to full correction in after years, she was able to wear the glasses with comfort.

CASE LXII. *Large amount of myopia: Small amount of astigmatism, but marked increase of vision by its correction; Full correction worn with comfort.* — March 15, 1898, Rebecca G., aged seventeen, in good health, came to the clinic of Drs. Lewis and Van Fleet, at the Manhattan Eye and Ear Hospital, for glasses, on account of poor vision, and because the glasses she had were not satisfactory. She had glasses fitted first when ten years of age. These glasses were changed after five years' time for the glasses that she is now wearing, − 11 D. in each eye.

Ophthalmometer. — Astigmatism with the rule, 2 D., 90° + or 180° − each eye.

R. V. = $\frac{4}{200}$: $\frac{20}{20}$ − W. − 13 D. − 1.50 D. cyl., 180°.

L. V. = $\frac{4}{200}$: $\frac{20}{20}$ − W. − 13 D. − 1.50 D. cyl., 180°.

Reads Jaeger No. 1, 5 to 15 inches.

The cylindrical glasses increased the vision from $\frac{20}{40}$ to $\frac{20}{20}$, a marked increase when we consider the amount of myopia present and the small amount of astigmatism.

Ophthalmoscope. — Myopia 15 D. in each eye; also a small posterior staphyloma in each eye.

Second test: the patient accepted the same glasses, and they were ordered for constant wear. Here again the glasses were very strong, but, as the patient had worn almost full correction for some time before, they were worn with entire comfort.

Moreover, the cylindrical glasses, though small in amount and with axis exactly at 180° in each eye (for this reason, as a rule, their effect could easily have been gotten by tilting the strong spherical glass, −13 D., slightly on the horizontal axes), were ordered in this case, because they so markedly increased the vision when added to the spherical glasses, and tilting of the spherical glasses did not give near so good vision.

Case LXIII. *Compound myopic astigmatism in one eye; Simple myopia of small amount in the other; Scopolamine used as a mydriatic.* — October 13, 1894, Miss M. R., aged thirty-one, in good general health, consulted me for burning and itching in the eyes, and for a strained feeling in them after using them for close work. She is a stenographer, and her eyes have troubled her more or less for the last year. She has no headaches, but there is a mild conjunctivitis present.

Ophthalmometer. — Astigmatism with the rule, .75 D., axis 90° + or 180° − right eye; .50 D., axis 90° + or 180° − left eye.

Test cards and trial lenses. —

R. V. = $\frac{20}{40}$: $\frac{20}{15}$ − W. − 1 D. − .25 D. cyl., 180°.

L. V. = $\frac{20}{30}$ + : $\frac{20}{15}$ − W. − .50 D.

Reads Jaeger No. 1, 6 to 15 inches.

Ophthalmoscope. — M. 1 D. right eye; M. .50 D. left eye.

There was some redness and injection of the conjunctiva with some scattering granulations on the palpebral conjunctiva. On this account, and the weak minus glasses being accepted, I thought perhaps the apparent myopia, as observed by the ophthalmoscope and as manifested by the glasses accepted, was due to a spasm of accommodation, even though the patient accepted the same glass time and again during the examination.

As the patient was in a hurry for the glasses, I instilled a solution of scopolamine (gr. ī to ℥ i), one drop in each eye, every five minutes, for six consecutive times, then waited one-half hour and tested, with the following result: —

R. V. = $\frac{20}{100}$: $\frac{20}{15}$ – W. – .75 D. – .50 D. cyl., 180°.

L. V. = $\frac{20}{100}$: $\frac{20}{15}$ – W. – .25 D. – .25 D. cyl., 180°.

The ophthalmoscope and ophthalmometer gave the same results as at the first test.

Third test, three days later, when the patient was not under the influence of the mydriatic, resulted as follows: —

R. V. = $\frac{20}{40}$: $\frac{20}{15}$ – W. – .75 D. – .50 D. cyl., 180°.

L. V. = $\frac{20}{30}$: $\frac{20}{15}$ W. – .50 D.

Reads Jaeger No. 1, 6 to 15 inches.

These last glasses were ordered, and have since been worn with comfort and satisfaction.

In very low degrees of myopia it is impossible at times to decide with the ophthalmoscope or the retinoscope (without the use of a mydriatic) whether myopia is present or not. And the mere acceptance of minus glasses by a patient is not positive evidence by any means that myopia exists, as hypermetropes, through spasm of accommodation, may, and often do, when improperly tested, accept minus glasses. Myopia of a low degree, 1 D. and less, rarely needs correction, unless there is a complicating astigmatism.

CASE LXIV. *Compound myopic astigmatism in one eye; Simple myopic astigmatism in the other; Asthenopia marked; Presbyopia.* — June 5, 1894, Mrs. M. S. C., aged fifty, in good general health, comes on account of severe headaches and pains in the eyes, especially after using the eyes for close work. She has worn glasses for fifteen or twenty years, constantly for the last ten years.

Ophthalmometer. — Astigmatism with the rule, 4 D., axis 125° + or 35° − right eye; 4 D., axis 55° + or 145° − left eye.

There is also some irregular astigmatism present in the right eye.

Test cards and trial lenses. —

R. V. = $\frac{20}{200}$: $\frac{20}{50}$ + W. − 3.50 D. cyl., 35°.

L. V. = $\frac{10}{200}$: $\frac{20}{20}$ − W. − 4 D. − 3.50 D. cyl., 145°.

Reads Jaeger No. 1, 6 to 13 inches with + 2 D. added for the presbyopia, which in effect would be: + 2 D. − 3.50 D. cyl., 35° right, and − 2 D. − 3.50 D. cyl., 145° left.

Ophthalmoscope. — M. 4 D. at 125° and Em. at 35° right eye; M. 8 D. at 55° and 4 D. at 145° left eye.

There are some diffuse corneal opacities on the cornea of the right eye, which accounts for the vision not being improved in that eye.

A second test was made and agreed with the first, and both the distance and reading glasses were ordered. Both pairs of glasses have been worn with comfort.

It is to the reading glasses I wish to call attention in this case. The patient, being fifty years of age, was presbyopic to the extent of 2 D. In the right eye she had simple myopic astigmatism, and either a cross-cylindrical or a sphero-cylindrical glass could be given. If a cross-cylindrical glass, it would take the following form: + 2 D. cyl., 125° − 1.50 D. cyl., 35°. A glance at Fig. 69 shows why this is so. The

emmetropic meridian at 35° becomes presbyopic by 2 D., and requires + 2 D. cylindrical glass at right angles to this meridian (at 125°) to correct it; while the presbyopia of 2 D. neutralizes 2 D. of the 3.50 D. of myopia in the meridian at 125°, thus leaving 1.50 D. of myopia in this meridian still to be corrected, which requires – 1.50 D. cyl., 35°. But instead of giving the cross-cylindrical glass, I chose the sphero-cylindrical + 2 D. – 3.50 D. cyl., 35°. First, because it was

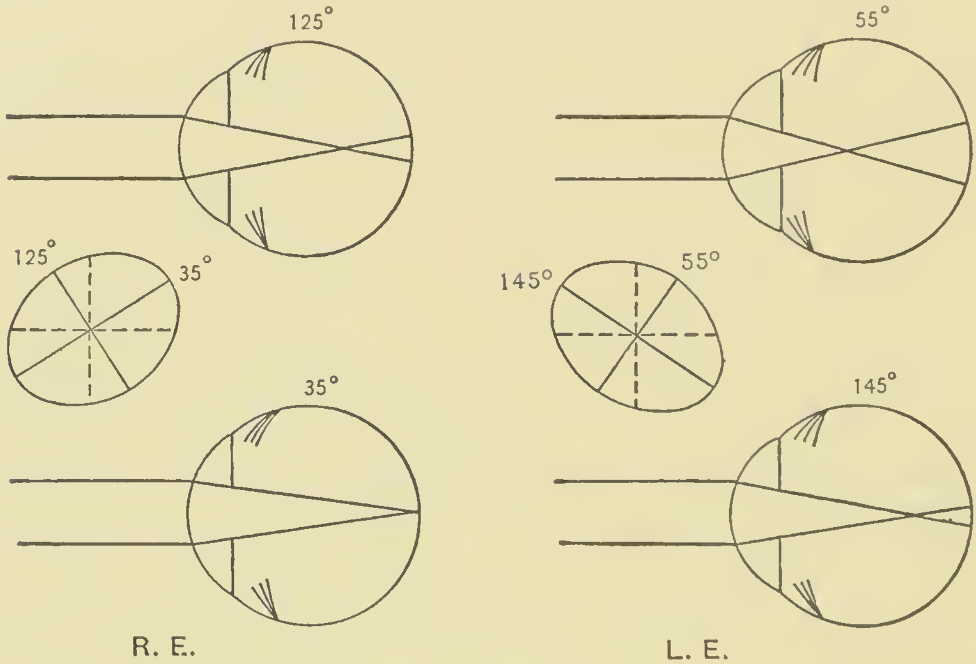


FIG. 69.

cheaper; second, because the astigmatism was not very large in amount, and the sphero-cylindrical glass in the right eye was made equal in weight with the opposite glass in the left eye.

The two glasses, the cross-cylindrical and the sphero-cylindrical, are exactly the same in effect, except that the cross-cylinders give a little wider field of vision. Thus the + 2 D. spherical glass combined with the – 3.50 D. cyl., 35°, acts with full force along the axis of the minus cylinder, that is, in the meridian at 35°, therefore acting as a + 2 D. cyl., axis 125°; and, at the same time, it neutralizes 2 D. of the 3.50 D. cyl. in

the meridian at 125°, leaving but 1.50 D. of this cylindrical glass to act in this (125°) meridian, thus acting exactly the same as a − 1.50 D. cyl., 35°.

I go particularly into these changes of glasses rendered necessary by the presence of presbyopia in myopic astigmatism, and have, in the chapter on simple myopic astigmatism, made diagrams of the changes of focus in the eye caused by presbyopia in such cases. For beginners especially, I think it most desirable to make diagrams of the foci of the two chief meridians of the eye, as indicated by the examination made and the glasses accepted, just as I have done in most of the cases so far reported ; then to note the effect and changes of focus that 1 D. of presbyopia causes in each meridian separately ; or what change 2 or 3 D., or whatever amount of presbyopia present would cause ; make diagrams of these latter foci, when no confusion as to the proper reading glass can arise. For instance, in the case just reported, right eye, for distant vision, the meridian at 35° is emmetropic, and focusses rays of light on the retina, while the meridian at 125° is myopic by 3.50 D., and focusses rays of light in front of the retina (see Fig. 69). Now, a presbyopia of 1 D. would cause the focus in each meridian to recede to the extent of 1 D. (as measured by glasses) for the reading distance, that is, the emmetropic meridian at 35° would focus back of the retina 1 D., and the myopic meridian at 125° would focus but 2.50 D.[1] in front of the retina, instead of 3.50 as for the distance. With 1 D. of presbyopia present in such a case as this, the correct reading glass would be, in cross-cylinders : + 1 D. cyl., 125° − 2.50 D. cyl., 35° ; or, in sphero-cylindrical, + 1 D. − 3.50 D. cyl., 35°.

[1] In speaking of the meridians focussing so many *diopters* in front or back of the retina, I am not unmindful of the fact that we usually speak of the focus as being at a certain *linear* distance in front or back of the retina. However, as this linear distance is fairly well expressed, relatively so at least, by the power of the glass it takes to correct the error, I have used the power of the glass as expressing these distances.

For 2 D. of presbyopia, which is actually present in this case, we have already shown what the correct reading glasses would be (see test). For 3 D. of presbyopia, the focus for the meridian at 35° for reading would be 3 D. back of the retina, and for the meridian at 125°, .50 D. in front of the retina. For correction, in cross-cylinders, it would take: + 3 D. cyl., 125° – .50 D. cyl., 35°; or, in sphero-cylindrical, + 3 D. – 3.50 D. cyl., 35° (or, if we chose to give a minus sphere and a plus cylinder, –.50 D. + 3.50 D. cyl., 125°, which would be a lighter glass in this instance). For 4 D. of presbyopia, the myopic astigmatism would be entirely neutralized, and the focus for reading in the meridian at 35° would be 4 D. back of the retina, while the focus for the meridian at 125° would also be back of the retina, to the extent of .50 D. In effect, therefore, for the reading distance, the patient is compound hypermetropic astigmatic, and would require for a reading glass, right eye, + .50 D. + 3.50 D. cyl., 125°.

In the present case, the left eye has 4 D. of myopia, in addition to the astigmatism of 3.50 D. Of course, it would take 4 D. of presbyopia to neutralize this myopia, before the astigmatism would be affected, and, after which, exactly the same change in glasses for the left eye would be required as has taken place in the right eye.

I am aware of the fact that this method of making diagrams of the foci of the chief meridians of the eye for the distance, then noting the change in focus brought about in each meridian for a certain amount of presbyopia, takes more time than the one of simple algebraic equations; but it has the great advantage of fixing the examiner's attention on the real condition and foci of the different meridians of the eye, thus making it a concrete case. With algebraic equations to ascertain the correct reading glass, it becomes a matter of abstract fact to a certain extent, and the observer, if he be a beginner, does not keep in mind the real condition of the eye, but fits the glasses

empirically. For example, take the left eye in the present case, where the distance glass accepted is − 4 D. − 3.50 D. cyl., 145°. At fifty years of age, with 2 D. of presbyopia present, the patient requires + 2 D. added to the distance glasses to get the correct reading glass. Algebraically it is : —

$$\begin{array}{l} -4\text{ D.} - 3.50\text{ D. cyl., } 145°. \\ +2\text{ D.} \\ \hline -2\text{ D.} - 3.50\text{ D. cyl., } 145°. \end{array} \qquad \ldots \quad \text{(I)}$$

For 4 D. of presbyopia it would be : —

$$\begin{array}{r} -4\text{ D.} - 3.50\text{ D. cyl., } 145°. \\ +4\text{ D.} \qquad\qquad\qquad\qquad \\ \hline - 3.50\text{ D. cyl., } 145°. \end{array} \qquad \ldots \quad \text{(II)}$$

Now this is perfectly correct in each instance, but if the examiner is not familiar with optics, unless he makes a diagram of the change of focus brought about by the presbyopia for the reading point, he will not likely have a clear idea of the real condition of the eye.

Antimetropia

The word *anisometropia* is often used for, and intended to convey the meaning of, the word *antimetropia*. Antimetropia means *opposite* state of refraction of the two eyes, myopic in nature in one eye and hypermetropic in the other, and is from the three Greek words, ἀντι, opposite, μέτρον, measure, and ῎οψις, vision; while anisometropia is from ἀνισος, unequal, μέτρον, measure, and ῎οψις, vision, and means an *unequal* state of refraction of the two eyes; that is, both eyes being either hypermetropic or myopic, one of the eyes is more hypermetropic or myopic than the other. Therefore, there is a distinct difference in the meaning of the two words, and they also indicate quite different conditions in the eyes, and they should not, on that account, be confounded one with the other, as is so often

done. Anisometropia is quite common, while antimetropia is rare.

Antimetropia is one of the most annoying errors of refraction, outside of conical cornea and irregular astigmatism, which are really pathological conditions rather than refractive, that we have to deal with. In some cases, in fact, one eye has to be fitted by itself, while the other has to be left alone, as the two cannot be made to work together. And this happens oftenest where the error is of large amount in one eye, associated with amblyopia; while the other eye has only a small or moderate error of refraction and with no amblyopia.

There are three or four reasons why antimetropes have trouble in using the two eyes together for binocular single vision. First, in such cases, it is difficult to fuse the poor image of the amblyopic eye with the clear image of the good eye so as to make but a single image in the brain center; second, for objects near at hand, it is difficult to converge the myopic or long eyeball to the same extent as the hypermetropic or short eyeball, again rendering single binocular vision difficult; third, if the myopia is of high degree and fully corrected, the patient will have difficulty in accommodating for near objects with that eye as compared with the hypermetropic eye, for its ciliary muscle is much weaker than that of the hypermetropic eye; fourth, the images of objects are different in size in the two eyes.

Some antimetropes are so fortunate as to be able to use the hypermetropic eye for distant vision and the myopic eye for near vision, thus using the eyes alternately and singly, and not together. In this way they are able to go without glasses, and make this, what to many is a veritable burden, an advantage in their favor over ordinary mortals. But they are the rare exceptions.

In many of these cases, where one eye is used constantly to the exclusion of the other, the unused eye drops out of the line

of vision and usually squints outward. However, I have known the amblyopic eye, which was highly myopic, to squint inward.

My plan of procedure in antimetropia is to fit the eyes separately, just as in other cases, and whatever glasses are accepted, have the patient wear them faithfully for a period of one month at least. If they do not give relief, I then usually leave the correction on the better eye, and place a plain glass in front of the bad eye. Each case, to a certain extent, is a law unto itself, however, and must be dealt with accordingly. A few concrete cases will give some idea how these patients are to be managed.

Case LXV. *Antimetropia with blepharitis marginalis; Simple hypermetropic astigmatism in one eye and simple myopic astigmatism in the other, with the rule in each eye.* — November 19, 1895, Nellie R., aged twenty-two years, in good general health, consulted me on account of great pain in the eyes, accompanied with severe headaches. She wanted very much to be relieved of redness of the eyelids, which remained irritated and more or less inflamed all the time.

Ophthalmometer. — Astigmatism with the rule, 1 D., axis $90°+$ or $180°-$ in each eye.

Test cards and trial lenses. — The vertical lines on the clock-dial were seen plainest with the right eye, and the horizontal lines were seen best with the left eye.

$$\text{R. V.} = \tfrac{20}{50} \quad : \tfrac{20}{20}\ \text{W.} - .50\ \text{D. cyl., } 180°.$$

$$\text{L. V.} = \tfrac{20}{20} + : \tfrac{20}{15}\ \text{W.} + .50\ \text{D. cyl., } 90°.$$

Reads Jaeger No. 1 from 6 to 17 inches.

Ophthalmoscope. — M. .75 D. at 90° and Em. at 180° right eye; Em. at 90° and H. .75 D. at 180° left eye.

A saturated solution of boracic acid was ordered as a wash for the eyelids, to be used twice a day; and the yellow oxide

of mercury ointment (gr. $\overline{\text{viii}}$ to ℥$\overline{\text{i}}$ vaseline) was ordered to be rubbed on the eyelids at bedtime.

After a week, in which time the lids improved but little, a second test was made for glasses. The patient accepted exactly the same glasses as at the first test. Ordered for constant wear: $-.50$ D. cyl., 180° right eye, and $+.50$ D. cyl., 90° left eye. Within a month the eyelids were well of their inflammation, the pains in the eyes and the headaches gone, and the patient happy. She has continued to wear the glasses

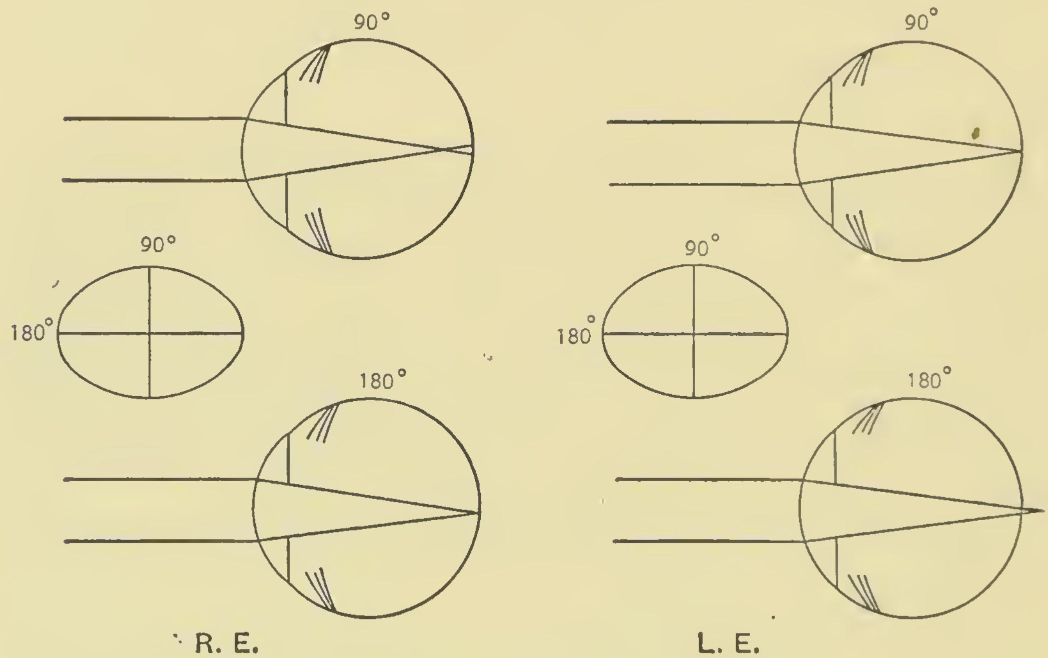


Fig. 70.

ever since with great satisfaction. With large errors of refraction of this nature, however, glasses do not usually give so good a result.

Attention may be called to the reading of the ophthalmometer in this case. The instrument read exactly the same amount and the same axis of astigmatism in each eye. Following my routine practice of beginning the test with weak plus glasses (cylinders where there is astigmatism), I found they would not be accepted by the right eye. I then tried a

weak minus cylinder, axis 180°, as indicated by the instrument, and it was accepted, a − .50 D. cyl., 180°, giving the best vision. Although I found simple myopic astigmatism in the right, I again followed my routine method of trying plus glasses first on the left eye, and found that they were accepted, a +.50 D. cyl., 90°, giving the best vision. Had minus cylindrical glasses been tried first on the left eye, I am convinced she would have accepted them, as she had on previous tests, and from which glass she got no relief from her asthenopia or red eyelids.

It must always be remembered that the ophthalmometer does not reveal to us the nature of the error of refraction, — that is, if hypermetropic or myopic, — but simply the axis and the amount of the corneal astigmatism. But, with this much known, by following the routine method already given in detail in previous pages of this book, nearly every case can be fitted correctly and without the use of a mydriatic.

Case LXVI. *Antimetropia; Amblyopia to some extent; Simple hypermetropic astigmatism in one eye, and simple myopic astigmatism in the other, with the rule in each.* — February 13, 1897, M. F., aged eighteen, in good health, consulted me for glasses on account of poor vision, and because of pain in the eyes and headaches when she persists in using the eyes.

Ophthalmometer. — Astigmatism with the rule, 2 D., axis 75° + or 165° − right eye; 2 D. with the rule, axis 105° + or 15° − left eye.

Test cards and trial lenses. —

$$\text{R. V.} = \tfrac{20}{70} - : \tfrac{20}{40}\ \text{W.} + 1.75\ \text{D. cyl., } 75°.$$

$$\text{L. V.} = \tfrac{20}{70} - : \tfrac{20}{40}\ \text{W.} - 1.75\ \text{D. cyl., } 15°.$$

Reads Jaeger No. 1 from 6 to 12 inches, and has single binocular vision.

Ophthalmoscope. — Em. at 75° and H. 2 D. at 165° right eye; M. 2 D. at 105° and Em. at 15° left eye.

A second and a third test resulted in the patient accepting the same glasses as at the first test. Ordered + 1.75 D. cyl.,

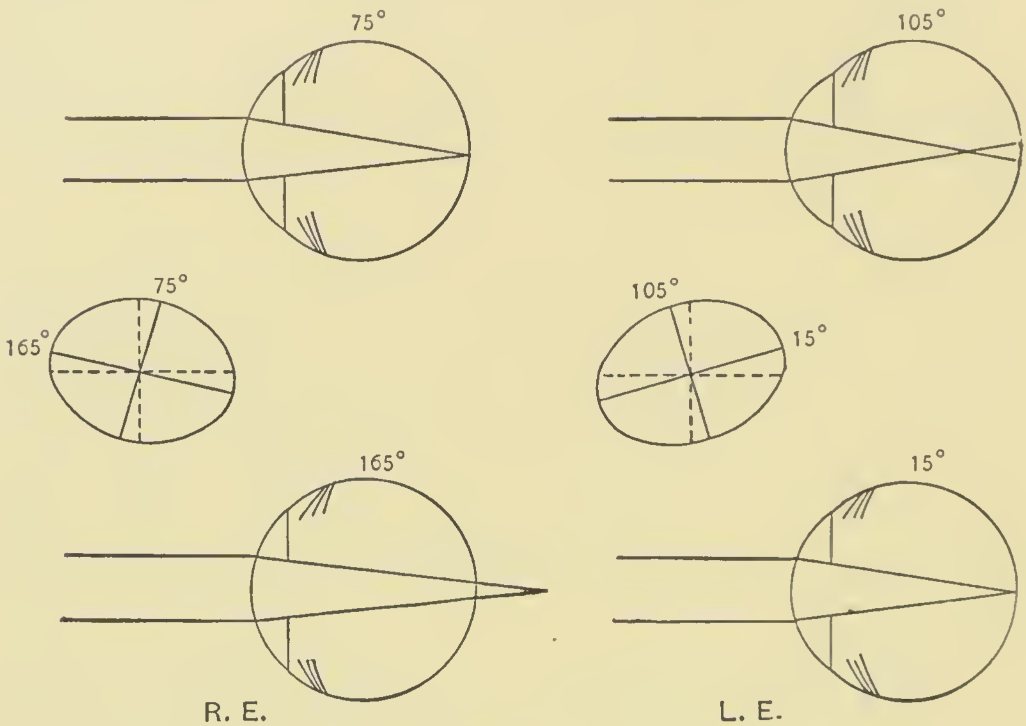


FIG. 71.

75° right eye, – 1.75 D. cyl., 15° left eye. These glasses have been worn for more than a year, with relief from her asthenopic vision.

CASE LXVII. *Antimetropia; Asthenopia; Simple hypermetropic astigmatism in one eye, and compound myopic astigmatism in the other, with the rule in each.* — August 11, 1896, James McG., aged thirty years, came to the clinic of Drs. Lewis and Van Fleet, at the Manhattan Eye and Ear Hospital, because of pain in his eyes and on account of severe headaches. His eyes have always given him trouble, both for far and near vision. The pains in the head are confined to the frontal region chiefly.

Ophthalmometer. — Astigmatism with the rule, 1 D., axis 90° + or 180° – in each eye.

Test cards and trial lenses. —

R. V. = $\frac{20}{30}$ – : $\frac{20}{15}$ W. +.50 D. cyl., 90°.

L. V. = $\frac{20}{50}$ – : $\frac{20}{15}$ W. – 1 D. – .50 D. cyl., 180°.

Reads Jaeger No. 1, 5 to 12 inches.

Ophthalmoscope. — Em. at 90° and H. .50 D. at 180° right eye; M. 1.50 D. at 90° and M. 1 D. at 180° left eye.

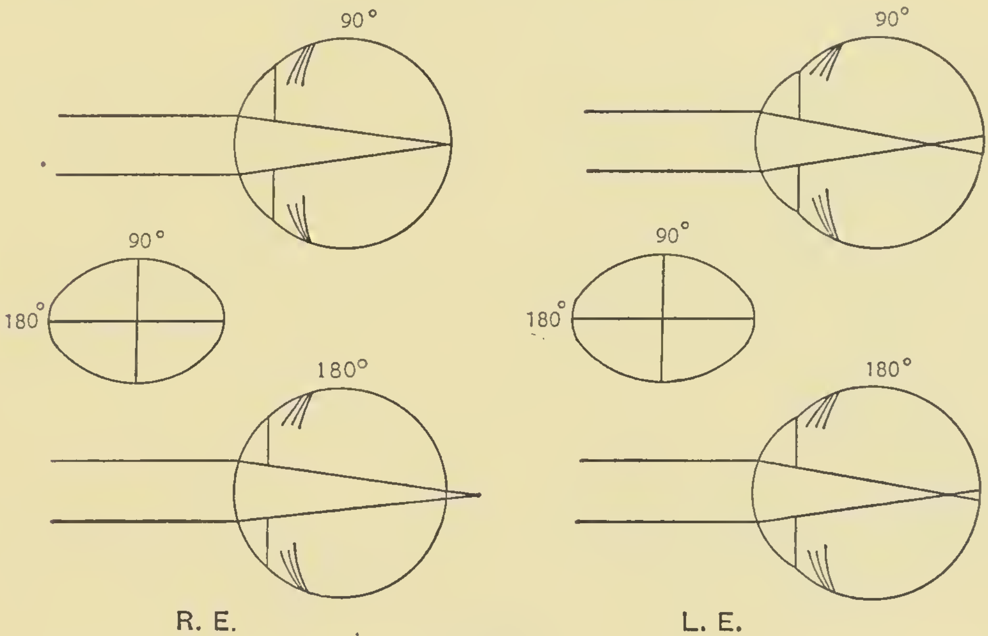


Fig. 72.

Second test: the patient accepted exactly the same glass as at the first test, and it was ordered. It took two weeks persistent wearing before the patient got accustomed to the glasses; but at the end of that time his eyes were entirely comfortable and his headaches relieved. After the first month the patient was lost sight of.

Case LXVIII. *Antimetropia; Compound hypermetropic astigmatism in one eye and compound myopic astigmatism in the other, against the rule in the myopic eye and with the rule in the*

hypermetropic eye; Marked asthenopia relieved with glasses.—November 19, 1895, Harriet W., aged twelve years, in good health, consults me on account of blurred vision and headaches, especially annoying in the afternoon at school. She has worn glasses, but without relief.

Ophthalmometer. — Negative right eye; astigmatism with the rule, .75 D., axis 90° + 180° – left eye.

Test cards and trial lenses. —

R. V. = $\frac{20}{70}$: not improved.

L. V. = $\frac{20}{30}$: $\frac{20}{20}$ W. + 1. D.

Reads Jaeger No. 1 from 5 to 12 inches. Signs of spasm of accommodation are present.

Ophthalmoscope. — M. 1 D. right eye; H. .50 D. at 90° and H. 1 D. at 180° left eye.

On account of a conjunctivitis, an astringent wash was ordered for the eyes, and the patient directed to come again in three days.

Second test: the ophthalmometer read the same as at the first test.

Test cards and trial lenses. —

R. V. = $\frac{20}{50}$: $\frac{20}{20}$ W. – .50 D. – .50 D. cyl., 105°.

L. V. = $\frac{20}{30}$: $\frac{20}{15}$ W. + .50 D. + .50 D. cyl., 90°.

Reads Jaeger No. 1, 5 to 15 inches.

Ophthalmoscope. — M. .50 D. at 105° and M. 1 D. at 15° right eye; H. .50 D. at 90° and H. 1 D. at 180° left eye.

On a third test the patient accepted the same glasses as on the second test, and they were accordingly ordered. They have been worn for more than two years with relief from all asthenopic symptoms.

In this case the ophthalmometer showed no corneal astigmatism in the right eye, and, as usual in such cases, the patient accepted a cylindrical glass against the rule

On the first test there was some spasm of accommodation, due to irritation of the eye from a mild conjunctivitis. After a few days' treatment this disappeared, the second and third tests agreed, and the glasses were ordered.

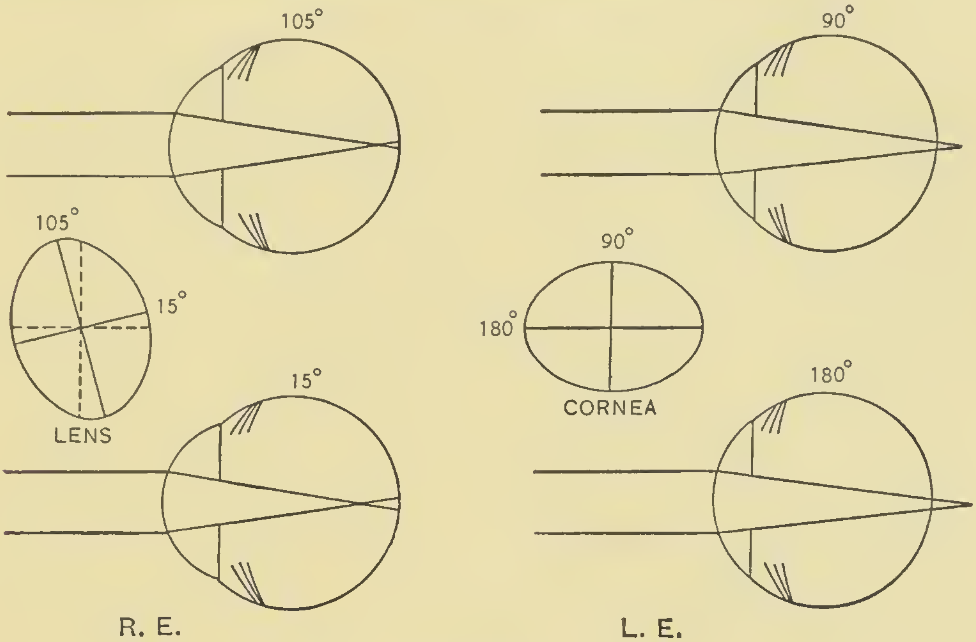


Fig. 73.

Case LXIX. *Antimetropia; Mixed astigmatism right, and compound myopic astigmatism left, eye; Head carried to the right side; Asthenopia; Relief with glasses.* — November 22, 1897, Mary McG., aged twenty-three years, in good health, consulted me on account of headaches and pains in the eyes. She has a tendency to hold her head to the right, especially for close work. Her left eye has troubled her a great deal for the last eighteen months, and sometimes sharp pains shoot through it. The left eye is very sensitive to bright light and heat.

Ophthalmometer. — Astigmatism with the rule, 2.50 D., axis 45° + or 135° – right eye; 2.50 D., axis 60° + or 150° – left eye.

Test cards and trial lenses. —

R. V. = $\frac{20}{200}$: $\frac{20}{40}$ – W. + 2 D. cyl., 45° – .50 D. cyl., 135°.

L. V. = $\frac{1}{200}$: $\frac{20}{100}$ W. – 10 D. – 2. D. cyl., 150°.

Reads Jaeger No. 1, 6 to 10 inches, with the right eye. Single binocular vision is not present.

Ophthalmoscope. — H. 1 D. at 135° and M. 1 D. at 45° right eye; M. 13 D. at 60° and 11 D. at 150° left eye.

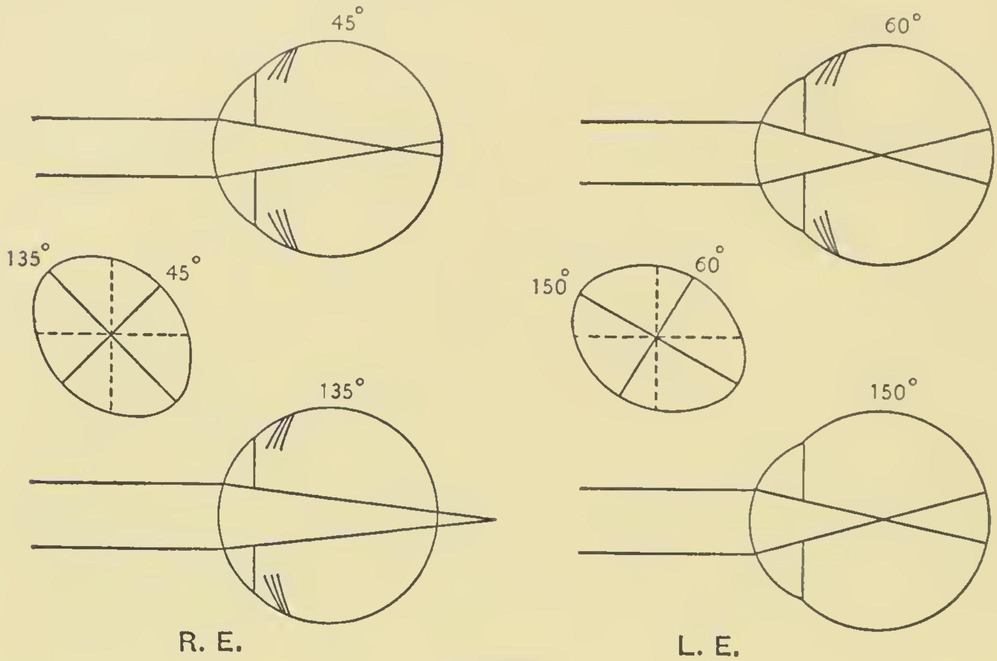


FIG. 74.

Second test: two days later the ophthalmometer gave the same reading.

Test cards and trial lenses. —

R. V. = $\frac{20}{200}$: $\frac{20}{40}$ + W. + 1 D. cyl., 45° − 1 D. cyl., 135°.

L. V = $\frac{2}{200}$: $\frac{20}{100}$ W. − 10 D. − 2 D. cyl., 150°.

A third test coincided with the second, and the glasses were ordered. The patient has been greatly benefited, the pain in the eyes and head disappeared after about two weeks' time; and after the first month she has been able to hold her head straight. She wore these glasses continuously till November 22, 1898, just one year, when she returned, complaining of pain in the right eye. On examination I found that the astigmatism had increased one-quarter of a diopter, and had

changed axis to the extent of 10°, that is, from 45° to 35°, and from 135° to 125°, respectively. The patient accepted + 1 D. cyl., 35° – 1.25 D. cyl., 125° right eye. The left eye had not changed, and the old glass was left. The new glass has relieved the pain in the right eye, and the patient is again comfortable, and carries her head perfectly straight.

CASE LXX. *Antimetropia; Simple hypermetropia right eye; Simple myopia of large amount with convergent strabismus left eye; Correction of strabismus with glasses without operation.* — March 10, 1892, Emma S., aged eighteen years, in poor health, consulted me on account of a trachoma and convergent strabismus of the left eye. She is anæmic and much run down, has but poor appetite, and is now under treatment for nervous dyspepsia. There is considerable inflammation in the lids, with some discharge.

After five months' treatment of the lids with the usual local applications, and with general tonics, the patient's condition was greatly improved in every way. At the end of this time I gave the first test for glasses as follows: —

Ophthalmometer. — Astigmatism with the rule, .50 D., axis 90° + or 180° – each eye.

Test cards and trial lenses. —

$$\text{R. V.} = \tfrac{20}{30} : \tfrac{20}{20} + \text{W.} + \ 1\text{ D.}$$

$$\text{L. V.} = \tfrac{2}{200} : \tfrac{20}{200}\ \text{W.} - 16\text{ D.}$$

Reads Jaeger No. 1, 6 to 15 inches, with the right eye.

Ophthalmoscope. — H. 1.50 D. right eye; M. 17 D. left eye, with posterior staphyloma, choroiditis, and floating bodies in the vitreous.

Second test: this corresponded with the first, and + 1 D. right eye and – 10 D. left eye were ordered, to be worn constantly. After about six weeks' time the left or myopic eye no longer squinted, which was most gratifying both to the patient and myself.

The patient has been under my observation for six years, and the eyes remain perfectly straight, although she has not single binocular vision.

I account for the correction of the convergent strabismus in the myopic eye by means of glasses in this case in exactly the way as the ordinary convergent squint of hypermetropia is corrected by glasses, as follows: the patient, being in poor health and having 1 D. of manifest hypermetropia in the right eye, converged the left amblyopic eye unduly inward in order to assist the accommodation in the right eye, that is, squinted the left eye inward. When the manifest hypermetropia in the right eye was corrected with a plus glass, there was no need of extra accommodative power in that eye, so the patient no longer squinted or converged the left eye too far inward, but relaxed this effort, and the left eye became straight; that is, parallel with the right.

CHAPTER VII

MIXED ASTIGMATISM—ILLUSTRATIVE CASES

PERHAPS mixed astigmatism is the most troublesome error of refraction which we are called upon to correct, and many oculists never attempt to correct a case of mixed astigmatism without the use of a mydriatic. To beginners, such cases are puzzling, and the examiner is often led to make prolonged and unnecessary tests. As for myself, I never think of using a mydriatic in mixed astigmatism, unless there is a tendency to, or an actual spasm of, accommodation, any more than I do in cases of simpler errors of refraction.

The ophthalmometer scores one of its greatest triumphs in just these cases, and does away with the necessity and bother of using a mydriatic. I grant, however, retinoscopy is a valuable method of testing where a mydriatic is used. But the use of a mydriatic is just what we wish to avoid if possible. With the use of the ophthalmometer and a routine method of testing the cases, we are able, in the great majority of cases, to avoid the use of a mydriatic altogether. On the other hand, to make retinoscopy effective in these cases, or in any other for that matter, a mydriatic must be used.

I begin my test in these cases in exactly the same manner as in all others, that is, I ascertain with the ophthalmometer the amount and axis of the corneal astigmatism. Say, for example, the instrument reads astigmatism with the rule, 2.50 D., axis 90° + or 180° −. The first glass that I try is a + .25 D. cyl., 90°. If this improves vision, I gradually increase its strength (+ .25 D. at a time) until the plus cylin-

drical glasses cease to improve the vision. By way of illustration in this supposed case, say the patient accepted + 1 D. cyl., 90°, and the vision was improved from $\frac{20}{100}$ to $\frac{20}{50}$, but that when a + 1.25 D. cyl., 90°, was tried it made the vision worse. Now, since the instrument showed the patient to have 2.50 D. of astigmatism, and as he accepted only 1 D. of that amount in plus glasses, I would immediately suspect mixed astigmatism, especially if a weak plus spherical glass in addition to the cylinder did not further improve vision. I would then try a − .25 D. cyl., 180°, that is at right angles to the plus cylinder. If this improved vision, it should be increased in strength, a quarter diopter at a time, until the vision ceased to be improved thereby, being careful to stop with the weakest minus glass that gave the best vision. We will say − 1 D. cyl., 180°, in this instance, and that the vision was further improved over that obtained by the plus cylinder alone, $\frac{20}{50}$ to $\frac{20}{30}$, with the two cylinders combined. This would indicate a case of mixed astigmatism, equally divided as to hypermetropia and myopia, or 1 D. of each, and 2 D. of astigmatism all told. Deducting .50 D. from the reading of the ophthalmometer (which was 2.50 D.), since the astigmatism was "with the rule," it leaves just 2 D. of astigmatism to be corrected. Of course, a second test should be given in all cases of mixed astigmatism, and if the glasses on the second test agree with the first test, I do not hesitate to give them. Sometimes it is necessary to give a third test. I may say it is exceptional for me not to be able to fit such cases without the use of a mydriatic.

Knowing the amount of the astigmatism from the reading of the instrument, we can readily see how close the astigmatism, as indicated by the glasses accepted, corresponds with it. In this way we are put on guard against giving too strong minus cylinders in such cases, as is often done, especially where the test is improperly begun with minus glasses.

Since it is of great importance in ordinary cases to begin the test for glasses with plus glasses, how much more important is it to begin the test with plus glasses in these cases of mixed astigmatism? And we must do so, unless we wish to give too strong minus cylinders, or use a mydriatic, neither of which alternatives is necessary. In fact, I have seen not a few cases of mixed astigmatism fitted with minus cylindrical glasses. So easy is it to fall into this error, that I venture to present a diagram of such a case, and in this way demonstrate how such mistakes are made. I thus hope to keep beginners from blundering.

As an example, we will take the case just cited above, where the ophthalmometer read astigmatism with the rule, 2.50 D., axis 90° + or 180° –, and the patient accepted + 1 D. cyl., 90° – 1 D. cyl., 180°.

Now, if instead of beginning the test with weak plus cylindrical glasses, as we did, say we began with minus cylinders, and gradually increased them in strength. In place of stopping with – 1 D. cyl., 180°, the exact correction of the myopic astigmatism, the patient would most likely have accepted – 2 D. cyl., 180°, the total amount of the astigmatism present. In this way the mixed astigmatism is converted into a simple hypermetropia of 1 D.

A glance at Fig. 75 will show how this is brought about. The – 2 D. cyl., 180°, not only corrects the myopia of 1 D. in the vertical meridian, but diverges the rays in that meridian 1 D. back of the retina. Now, since the eye is already hypermetropic 1 D. in the horizontal meridian, we evidently have in effect 1 D. of simple hypermetropia present; which *induced* hypermetropia, by the way, the patient can and often will correct by the use of the ciliary muscle, since he now can use it in its entire circumference. Not only can the patient do this, but, if his accommodative power is strong, he sometimes does it with comfort. Hence the relief for a time from asthenopia

sometimes in mixed astigmatism, even with simple minus cylindrical glasses.

Incidentally, I might say, a case similar in effect to this is where a patient with simple hypermetropic astigmatism accepts a simple myopic cylindrical glass. For example, say a patient should wear a + 1 D. cyl., 90°, to correct a simple hypermetropic astigmatism of that amount. Now instead of this he will sometimes accept – 1 D. cyl., 180°, especially so if minus

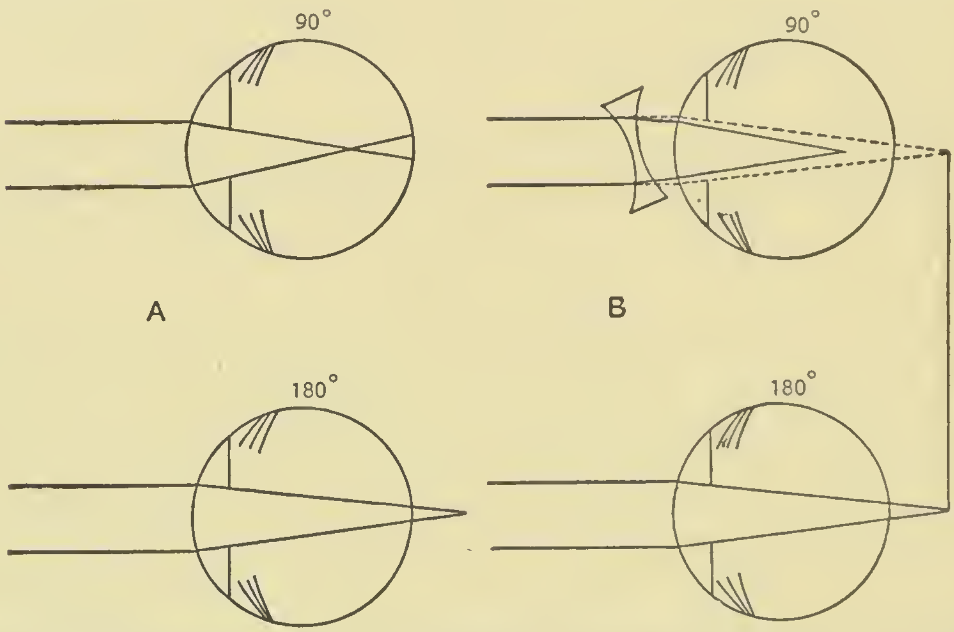


FIG. 75. — (*A*) Before correction. (*B*) After correction with – 2 D. cyl., axis 180°, the mixed astigmatism is converted into a simple hypermetropia of 1 D.

cylindrical glasses are begun with. The – 1 D. cyl., 180°, converts the patient's simple hypermetropic astigmatism into a simple hypermetropia of 1 D. (see Fig. 76).

The patient by means of his accommodative power can correct this simple hypermetropia (as produced by the minus cylinder) with comfort at times, because he can use the whole of the ciliary muscle regularly ; while he could not correct the simple hypermetropic astigmatism without discomfort, since, in that case, it must contract irregularly to act on the horizontal meridian of the lens without at the same time acting on the

vertical meridian, which is emmetropic and should be let alone. Such is the simple explanation of these cases. No stronger plea could be urged for the beginning of all tests with plus glasses, I am sure.

To recapitulate: most cases of mixed astigmatism can be correctly fitted with glasses without the use of a mydriatic, provided that first, the amount and axis of the corneal astigmatism be ascertained; next, that the test for glasses be begun

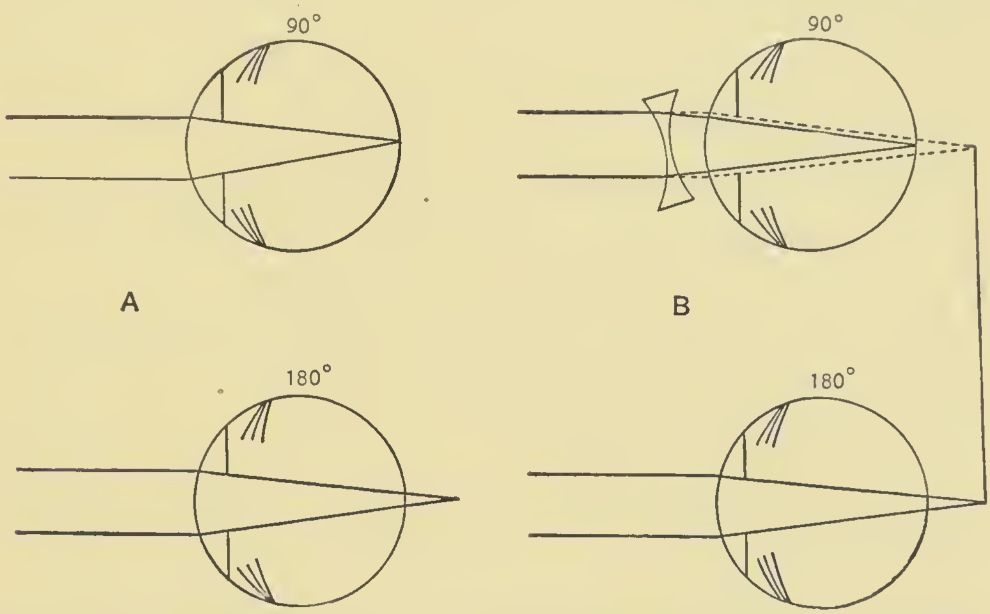


FIG. 76. — (*A*) Before correction. (*B*) After correction with − 1 D cyl., 180°, by which the simple hypermetropic astigmatism is converted into a simple hypermetropia of 1 D.

with weak plus glasses and their strength gradually increased; and finally minus glasses tried.

The chief indication for a mydriatic in such cases, as in all other cases of refractive error, is a spasm of accommodation. The means of detecting spasm of accommodation have already been pointed out elsewhere, so we need not consider them again.

CASE LXXI. *Mixed astigmatism of large amount and with the rule in each eye; Asthenopia; Relief with glasses.*—April 21,

1893, Miss S. A., aged twenty-two years, in good general health, has had trouble with her eyes for the last six years. She now complains of having to hold the print too close to her eyes when she reads, also of headache and pain in the eyes after reading or sewing. She has three brothers and one sister, none of whom are troubled with their eyes.

Ophthalmometer. — Astigmatism with the rule, 4 D., axis 75° + or 165° – right eye; 5 D., axis 95° + or 5° – left eye.

Test cards and trial lenses. —

R. V. = $\frac{10}{200}$: $\frac{20}{40}$ W. + 1.75 D. cyl., 75° – 1.75 D. cyl., 165°.

L. V. = $\frac{10}{200}$: $\frac{20}{50}$ W. + 3.25 D. cyl., 95° – 1 D. cyl., 5°.

Reads Jaeger No. 1 from 8 to 15 inches.

Ophthalmoscope. — M. 2 D. at 75° and H. 2 D. at 165° right eye; M. 1 D. at 95° and H. 4 D. at 5° left eye.

Second test: three days later the ophthalmometer gave exactly the same reading as at the first test.

Test cards and trial lenses. —

R. V. = $\frac{10}{200}$: $\frac{20}{40}$ W. + 2 D. cyl., 75° – 1.50 D. cyl., 165°.

L. V. = $\frac{10}{200}$: $\frac{20}{50}$ W. + 3.50 D. cyl., 95° – .75 D. cyl., 5°.

The ophthalmoscope agreed practically with the first examination. I ordered the glasses that were accepted on the second test in sphero-cylinders, to wit: – 1.50 D. + 3.50 D. cyl., 75° right; and – .75 D. + 4.25 D. cyl., 95° left. These glasses have been worn with great satisfaction from the first, and have not been changed.

It will be noticed that I ordered a sphero-cylindrical glass instead of cross-cylinders. In this instance I gave sphero-cylinders, because by actual trial in the trial frames the sphero-cylinders were more comfortable to the patient and gave equally as good vision. It will be seen also that I gave a minus sphere with a plus cylinder. There was a reason for this. In this case the minus spheres combined with plus cylinders is a

much lighter glass than had we given plus spheres with minus cylinders. For example, take the glass for the left eye: − .75 D. + 4.25 D. cyl., 95°, is a much lighter glass than + 3.50 D. cyl., 95° − 4.25 D. cyl., 5°, though the glasses are identical in effect with each other, as they are, indeed, with the cross-cylinders, + 3.50 D. cyl., 95° − .75 D. cyl., 5°, from which they are transposed.

Where we have mixed astigmatism in one eye only, when we convert a cross-cylinder into a sphero-cylinder we have to

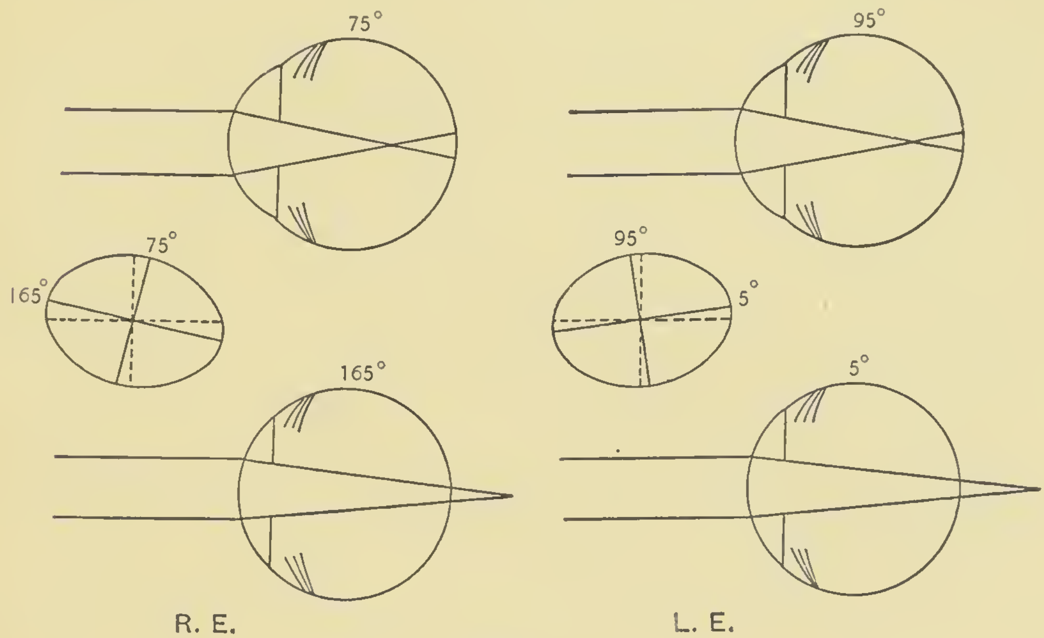


FIG. 77.

pay some regard to the axis of the cylinder in the other eye, if astigmatism of a simple or compound nature is present — a point which will be illustrated by cases to follow.

In small and moderate degrees of mixed astigmatism, instead of giving cross-cylinders, a sphero-cylinder is most often to be preferred, for the reason that it is a cheaper glass than the cross-cylinders. But in high degrees of mixed astigmatism cross-cylinders are to be preferred to sphero-cylinders, because they give a broader field of vision. The method of converting

cross-cylinders into sphero-cylinders is a very simple one ; if you please, the simplest of algebraic equations. For the benefit of any one who may not understand algebraic equations, I may say that I shall use the simplest terms, so that even they may understand the method. I will give a concrete case in order to illustrate the more plainly. Take the last case cited, right eye, where the patient accepts a + 2 D. cyl., 75° – 1.50 D. cyl., 165°. To convert this into a sphero-cylinder (plus sphere with a minus cylinder) give a + 2 D. sphere in place of the 2 D. cyl., then transpose 2 D. to the opposite side of the equation, changing the sign with the transposition, and add this amount (2 D.) to the – 1.50 D. cyl., which would give – 3.50 D. cyl., 165°, the axis of the minus cylinder remaining unchanged. The transposed glass is written thus : + 2 D. – 3.50 D. cyl., 165°.

To convert this same cross-cylinder into a sphero-cylinder (minus sphere with a plus cylinder) give a – 1.50 D. sphere in place of the – 1.50 D. cyl., then transpose – 1.50 D. to the opposite side of the equation, changing the sign in the transposition, and add this amount (1.50 D.) to the + 2 D. cyl., which would give + 3.50 D. cyl., 75°, the axis of the plus cylinder remaining unchanged. The transposed glass is written thus : – 1.50 D. + 3.50 D. cyl., 75°.

In other words, if we wish to convert a cross-cylinder into a sphero-cylinder (a plus sphere with a minus cylinder). all that it is necessary to do is to give in place of the plus cylinder a plus sphere of equal strength, then add this amount to the strength of the minus cylinder, leaving its axis unchanged. If we wish to convert it into a sphero-cylinder (minus sphere with a plus cylinder), all that is necessary to do is to give in place of the minus cylinder a minus sphere of equal strength, and add this same amount to the plus cylinder, leaving its axis unchanged.

This explanation I am sure is plain enough, even to a man who never heard of algebra.

A glance at Fig. 77 will show how each of the three glasses, —

(1) + 2 D. cyl., 75° − 1.50 D. cyl., 165°;

(2) + 2 D. − 3.50 D. cyl., 165°;

(3) − 1.50 D. + 3.50 D. cyl., 75°;

which are the cross-cylinder and the sphero-cylinders into which it is capable of being converted, can correct the mixed astigmatism in the right eye.

With glass No. 1, the cross-cylinder, the + 2 D. cyl., 75°, corrects the hypermetropia at 165° (cylinders always acting at right angles to their axes), while the − 1.50 D. cyl., 165°, corrects the myopia at 75°; thus the eye is rendered emmetropic, or corrected. With glass No. 2, the + 2 D. corrects the hypermetropia at 165°; but, since it acts in its whole circumference, it makes the myopia worse to that extent (2 D.) in the meridian at 75°, consequently that amount has to be added to the − 1.50 D. cyl., making it − 3.50 D. cyl., 165°. With glass No. 3, the − 1.50 D. corrects the myopia in the meridian at 75°; but here again, since it acts in its entire circumference, it makes the hypermetropia worse to that extent (1.50 D.) in the meridian at 165°; therefore that amount has to be added to the + 2 D. cyl., making it + 3.50 D. cyl., 75°.

As a rule, when converting cross-cylinders into sphero-cylinders, the weaker cylinder should be converted into the sphere and the same amount added to the stronger cylinder; because such a combination makes a lighter glass than where the stronger cylinder is converted into a sphere and the weaker cylinder added to it (see example, p. 181, this chapter). However, in making a choice, some regard must be paid to the opposite eye, if astigmatism is present in that eye, and especially if not of the mixed variety. Several concrete cases will serve to illustrate these points better than mere statements.

CASE LXXII. *Mixed astigmatism of large amount, with the rule and at off axes; Marked asthenopia, severe headaches, dizziness; Relief with glasses.* — February 27, 1897, Mrs. F. E. P., aged twenty-six years, in good health, has worn glasses at times since a child, but none of the glasses were satisfactory. When she reads, her eyes and head ache, and if she persists in reading for any considerable length of time, she becomes dizzy.

Ophthalmometer. — Astigmatism with the rule, 5 D., axis 105° + or 15° − right eye; 6 D., axis 75° + or 165° − left eye.

Test cards and trial lenses. —

R. V. = $\frac{15}{200}$: $\frac{20}{70}$ W. + 1 D. cyl., 105° − 3.50 D. cyl., 15°.

L. V. = $\frac{15}{200}$: $\frac{20}{70}$ W. + 1 D. cyl., 75° − 4.50 D. cyl., 165°.

Reads Jaeger No. 1, $5\frac{1}{2}$ to 12 inches.

Ophthalmoscope. — M. 4 D. at 105° and H. 1 D. at 15° right eye; M. 5 D. at 75° and H. 1 D. at 165° left eye.

Second test: four days later the ophthalmometer gave the same reading in the right eye, but varied 5° as to the axis in the left eye, giving 6 D., axis 70° + or 160° −.

Test cards and trial lenses. —

R. V. = $\frac{15}{200}$: $\frac{20}{50}$ W. + 1.25 D. cyl., 105° − 3.25 D. cyl., 15°.

L. V. = $\frac{15}{200}$: $\frac{20}{70}$ W. + 1 D. cyl., 70° − 4.50 D. cyl., 160°.

Reads Jaeger No. 1, $5\frac{1}{2}$ to 12 inches.

This last glass was ordered as a sphero-cylinder (plus sphere with a minus cylinder). Usually, in a case with as large amount of mixed astigmatism as in this case, we prescribe cross-cylinders, because it gives a broader field of vision. But in this instance so much of the glass was minus and so little plus that I gave sphero-cylinders. Had the hypermetropic and myopic portions of the astigmatism been nearly or exactly equal, I should have

given cross-cylinders, because they would have given a broader field of vision than the sphero-cylinders.

Again, in the present case, although I converted the cross-cylinders into a sphero-cylinder, a plus sphere with a minus cylinder, I would not for a moment think to convert them into a sphero-cylinder with a minus sphere and a plus cylinder, because it would have made a very heavy glass, to wit: − 3.25 D. + 4.50 D. cyl., 105° right eye; − 4.50 D. + 5.50 D. cyl., 70° left eye. Although this glass is identically

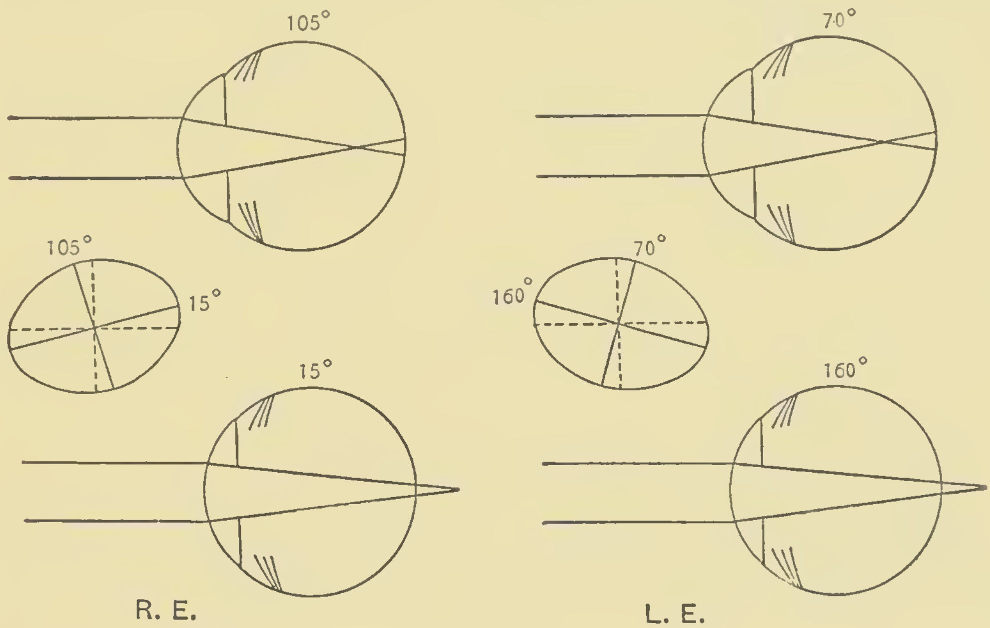


FIG. 78.

the same in effect as the cross-cylinder, and the sphero-cylinder with a plus sphere and a minus cylinder, it is not to be considered at all.

Sometimes in cases where the cross-cylinders and one of the sphero-cylinders into which it can be converted do not differ much in weight, as in the cross-cylinder and the sphero-cylinder (the one with a plus sphere and a minus cylinder) in the present case, I give a practical test to decide between the fitness of the two glasses. I first try the cross-cylinders, then the sphero-cylinders in the trial frame, and find with which the

patient sees best and most comfortably, and decide accordingly. Strange as it may seem, they often see considerably better with one glass than the other, although theoretically they are supposed to have the same effect.

CASE LXXIII. *Mixed astigmatism with the rule; No amblyopia; Persistent headaches; Relief with glasses.* — September 12, 1894, Annie S., aged forty years, in good health, has suffered from headaches all of her life. At times the headaches are very severe; in fact, neuralgic in character, and are intensified by any persistent use of the eyes.

Ophthalmometer. — Astigmatism with the rule, 3.50 D., axis 100° + or 10° − right eye; 3.50 D., axis 80° + or 170° − left eye.

Test cards and trial lenses. —

R. V. = $\frac{20}{40}$ − : $\frac{20}{20}$ + W. + .75 D. cyl., 100° − 2 D. cyl., 10°.

L. V. = $\frac{20}{40}$ − : $\frac{20}{20}$ + W. + .75 D. cyl., 80° − 2 D. cyl., 170°.

With both eyes at once, distant vision = $\frac{20}{15}$.

Reads Jaeger No. 1 from 8 to 18 inches.

Ophthalmoscope. — M. 2 D. at 100° and H. 1 D. at 10° right eye; M. 2 D. at 80° and H. 1 D. at 170° left eye.

The above glasses in the form of sphero-cylinders (+ .75 D. − 2.75 D. cyl., 10° right eye; + .75 D. − 2.75 D. cyl., 170° left eye) were prescribed after one test. They gave relief almost immediately, and have been worn with comfort ever since. Of late, however, she feels the need of a stronger glass for reading, especially at night, and this is to be expected as she is now forty-three years of age, and her presbyopia demands it.

It will be seen by this case that even cases of mixed astigmatism can be fitted correctly, not only without the use of a mydriatic, but at one sitting. Of course, the age of the patient, she being forty, favored the procedure. In patients under

forty years of age, in cases of mixed astigmatism, I always give two, and, in most cases three, tests before giving glasses.

The sphero-cylinder with a plus sphere and a minus cylinder was more desirable than the sphero-cylinder with a minus

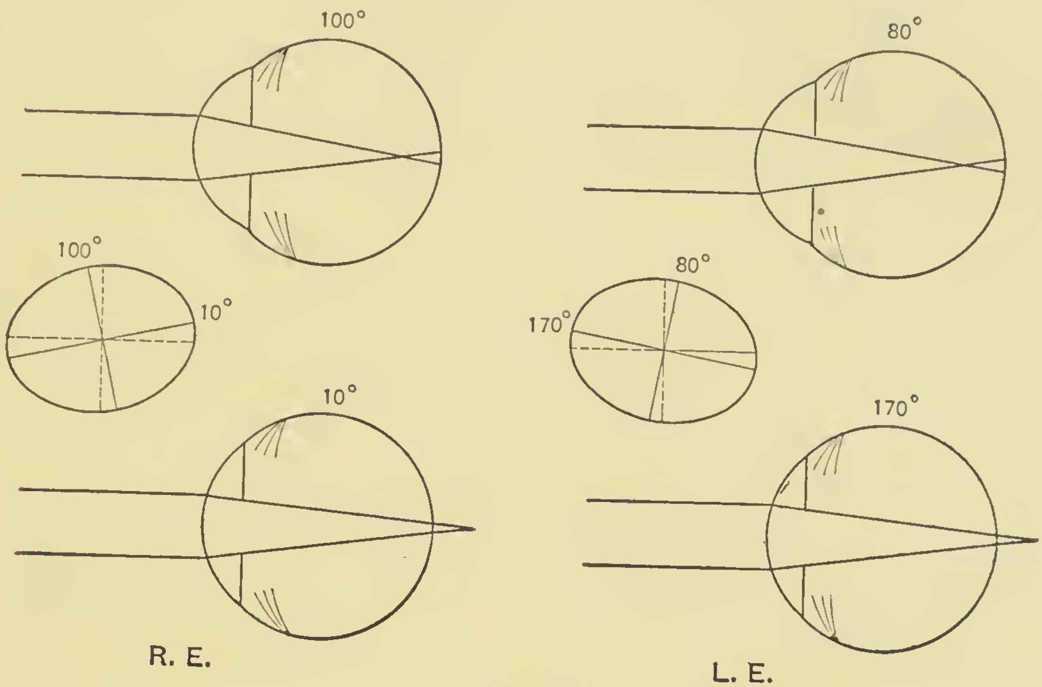


FIG. 79.

sphere and a plus cylinder, because lighter and with the axes of the cylinders horizontally placed, or nearly so, both points in its favor.

CASE LXXIV. *Mixed astigmatism with the rule in one eye; Hypermetropic astigmatism with the rule in the other eye; Asthenopia; Relief with glasses.* — December 19, 1894, Emily R., aged thirty-two years, in perfect health, has always suffered with severe headaches and with pain in the eyes. She has been wearing glasses for the last nine months, but without much relief from her asthenopic symptoms.

Ophthalmometer. — Astigmatism with the rule, 1 D., axis 80° + or 170° − right eye; 4.25 D., axis 105° + or 15° − left eye.

Test cards and trial lenses. — The lines in the horizontal meridian from III to IX are seen plainest in the right eye; the lines from IV to X are seen plainest with the left eye until + 1.25 D. cyl., 105°, is placed before the eye, when all of the lines appear alike, but somewhat blurred. And when the entire plus cylinder, 2.75 D., is placed in front of the eye, the lines from I to VII are seen plainest; but when − 1.50 D. cyl., 15°, is added to the plus cylinder in the frames, all of the lines appear alike and plainly.

R. V. = $\frac{20}{30}$: $\frac{20}{15}$ − W. + .50 D. cyl., 85°.

L. V. = $\frac{10}{200}$: $\frac{20}{70}$ W. + 2.75 D. cyl., 105° − 1.50 D. cyl. 15°.

Reads Jaeger No. 1 from 7 to 18 inches.

Ophthalmoscope. — H. 1 D. right eye; H. 2 D. at 15° and M. 2 D. at 105° left eye.

Second test: the ophthalmometer read the same exactly as at the first test.

Test cards and trial lenses. —

R. V. = $\frac{20}{30}$: $\frac{20}{15}$ W. + .50 D. cyl., 85°.

L. V. = $\frac{10}{200}$: $\frac{20}{70}$ W. + 2.50 D. cyl., 105° − 1.50 D. cyl., 15°.

The ophthalmoscope agreed with the first examination. Ordered: —

+ .50 D. cyl., 85° right eye;

− 1.50 D. + 4 D. cyl., 105° left eye.

I wish to call attention to two points in this case: first, the axis of the cylinder in the right eye varied 5° from the reading of the ophthalmometer; second, I converted the cross-cylinder in the left eye into a sphero-cylinder, — a minus sphere with a plus cylinder, — and for three reasons: (*a*) to make the cylinder correspond to the right eye; (*b*) because, in this case, it is a lighter glass than the sphero-cylinder with a plus sphere and a minus cylinder; and (*c*) a cheaper glass.

And this brings me to speak, in a general way, in reference to such cases as the present one, where there is a mixed astigmatism in one eye and simple or compound astigmatism in the other. In converting the cross-cylinders into sphero-cylinders, some regard must be had that the character (plus or minus) of the cylinder in the transposed glass correspond to the cylinder in the opposite eye. Because, as a rule, a plus cylinder on one eye and a minus cylinder on the other do not work as well as when both are positive or negative. This point should be

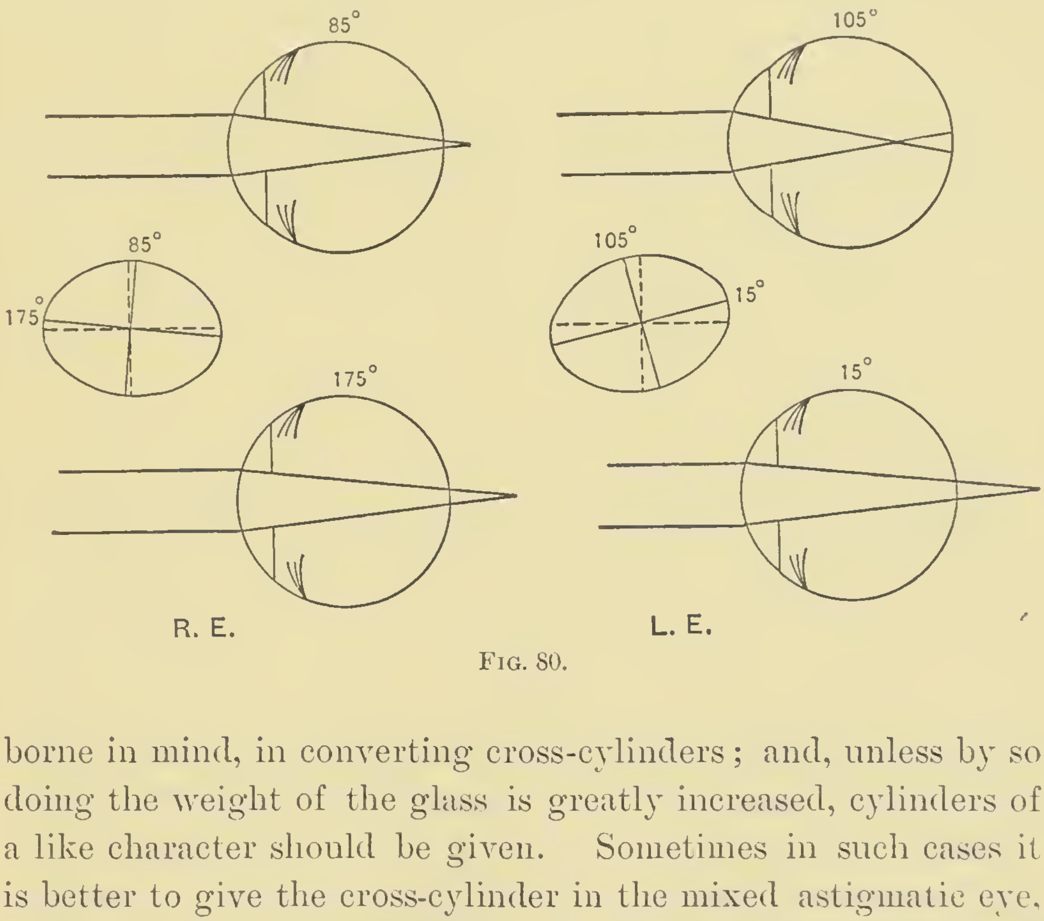


Fig. 80.

borne in mind, in converting cross-cylinders; and, unless by so doing the weight of the glass is greatly increased, cylinders of a like character should be given. Sometimes in such cases it is better to give the cross-cylinder in the mixed astigmatic eye, especially if the astigmatism is of large amount, rather than convert it into a sphero-cylinder, either with plus sphere and minus cylinder, or minus sphere and plus cylinder; and, by putting the different combinations in front of the eye for a few moments, the patient will often make the choice for himself.

Case LXXV. *Mixed astigmatism with the rule right eye; Hypermetropic astigmatism with the rule left eye; Marked asthenopia; Spasm of accommodation; Atropine instilled; Relief with glasses.* — February 17, 1894, Pauline J., aged thirty years, is in good general health, but has suffered a great deal from headaches and pains in the eyes. It is almost impossible for her to use her eyes for close work of any kind, because of the severe headaches and discomfort in the eyes when she attempts such work.

Ophthalmometer. — Astigmatism with the rule, 4.50 D., axis 90° + or 180° – right eye; 1.50 D., axis 90° + or 180° – left eye.

Test cards and trial lenses. — The test with the lines on the clock-dial were thoroughly unsatisfactory, no definite result being obtained by them.

$$\text{R. V.} = \tfrac{10}{200}: \tfrac{20}{50}\ \text{W.} - 1\ \text{D.} - 4\ \text{D. cyl., } 180°.$$

$$\text{L. V.} = \tfrac{20}{40}: \tfrac{20}{30}\ \text{W.} - 1\ \text{D. cyl., } 180°.$$

Reads Jaeger No. 1 from 10 to 14 inches.

With the above glasses the patient would see very well for a few moments at a time, then everything would "fade out," as she expressed it. In fact, this happened several times during the test when the eyes were being tested separately. It is unnecessary for me to say that I began the test in each eye with my routine method of trying plus glasses first; but, as they were refused, minus glasses were next tried, with the above result.

I suspected spasm of accommodation from the way the eyes behaved during the test, the patient being uncertain of the glasses, and the letters fading out from time to time. The examination with the ophthalmoscope showed the patient to be mixed astigmatic in the right eye. Retinoscopy confirmed mixed astigmatism in the right eye, but left the diagnosis in

the left eye in doubt; in fact, indicated myopic astigmatism, which, under atropine, proved to be hypermetropic astigmatism.

I might say there were no muscle insufficiencies.

Atropine solution (4 gr. to ℥i) was ordered to be instilled, one drop in each eye, three times a day, for four days. Then a second test was made.

The ophthalmometer gave the same readings as at the first test.

Test cards and trial lenses.—

R. V. = $\frac{10}{200}$: $\frac{20}{50}$ W. + 2 D. cyl., 90° – 2 D. cyl., 180°.

L. V. = $\frac{20}{200}$: $\frac{20}{30}$ W. + 25 D. + 1.50 D. cyl., 90°.

Ophthalmoscope.—H. 2 D. at 180° and M. 2.50 D. at 90° right eye; Em. at 90° and H. 1.50 D. at 180° left eye.

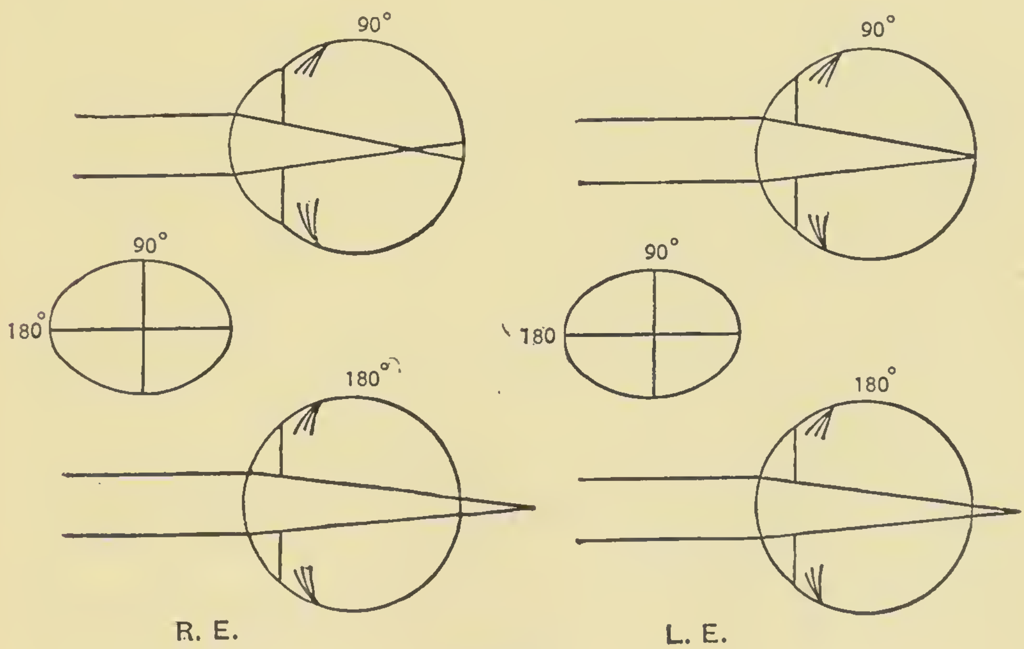


Fig. 81.

Ten days later, when the effects of the atropine had left the eyes, a third test was made. The ophthalmometer read uni-

formly with the two previous tests, and the subjective test, with the test cards and trial lenses, resulted in the patient accepting the same glasses as when under the influence of atropine, except that the +.25 D. sphere was not accepted by the left eye. They were accordingly ordered, a cross-cylinder +2 D. cyl., 90° − 2 D. cyl., 180° right eye, and + 1.50 D. cyl., 90° left eye. The cross-cylinders in the right eye gave a broader field and more clearly defined the letters than either of the sphero-cylinders into which it could be converted. However, had either of the sphero-cylinders been given, it would have been the minus sphere with plus cylinder, so that the cylinder would have corresponded both in character (plus) and in direction of axis (90°) with the cylinder in the opposite eye.

CASE LXXVI. *Mixed astigmatism with the rule left eye; Compound hypermetropic astigmatism with the rule right eye; Asthenopia; Relief with glasses.* — July 2, 1895, Ida S., aged thirty years, in good health, but has suffered considerably with headaches since a schoolgirl. She has had numerous glasses, but none have been comfortable or relieved the headaches.

Ophthalmometer. — Astigmatism with the rule, 1 D., axis 75°+ or 165°− right eye; 3 D., axis 120°+ or 30°− left eye.

Test cards and trial lenses. —

R. V. = $\frac{20}{20}$ − : $\frac{20}{15}$ W. + .25 D. + .50 D. cyl., 75°.

L. V. = $\frac{20}{200}$: $\frac{20}{20}$ W. + 1.25 D. cyl., 120° − 1.25 D. cyl., 30°.

Reads Jaeger No. 1 from 5 to 20 inches.

Ophthalmoscope. — H. 1 D. right eye; H. 1.50 D. at 30° and M. 1.50 D. at 120° left eye.

Second test: this resulted in the patient accepting exactly the same glasses as at the first test, and they were ordered: —

+ .25 D. + .50 D. cyl., 75° right eye;

− 1.25 D. + 2.50 D. cyl., 120° left eye.

In this case, as the mixed astigmatism was not of large amount and was equally divided between hypermetropia and myopia, I converted the cross-cylinder into a sphero-cylinder,

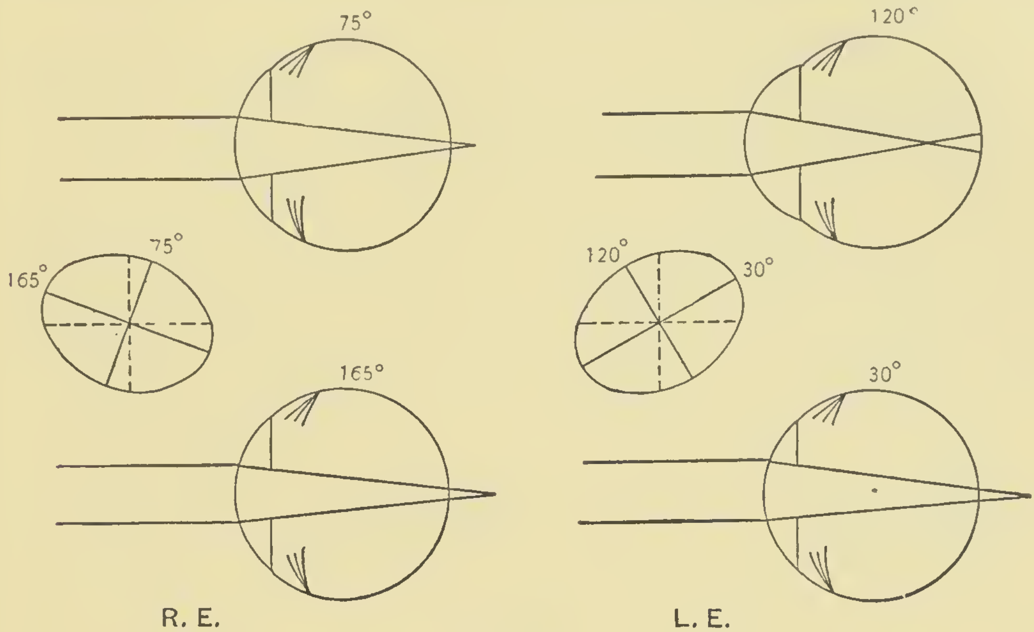


FIG. 82.

a minus sphere with a plus cylinder, so that the cylinder would correspond in character (plus) with the cylinder in the opposite eye.

These glasses have been worn with great comfort.

CASE LXXVII. *Mixed astigmatism with the rule left eye; Simple myopic astigmatism with the rule right eye; Amblyopia; Asthenopia; Relief with glasses.* — January 9, 1894, George B., aged thirty-five years, in good general health, but has been greatly troubled with his eyes for many years. He is compelled to hold reading matter too close to his eyes, and after using the eyes for close work, vision becomes painful and often headaches follow.

Ophthalmometer. — Astigmatism with the rule in each eye, 3.50 D., axis 105°+ or 15°− right eye; 5 D., axis 85°+ or 175°− left eye.

Test cards and trial lenses. —

R. V. = $\frac{20}{50}$: $\frac{20}{40}$ W. – 3 D. cyl., 10°.

L. V. = $\frac{20}{100}$: $\frac{20}{50}$ W. + 2 D. cyl., 80° – 2.50 D. cyl., 170°.

Reads Jaeger No. 1 from 6 to 12 inches.

Ophthalmoscope. — M. 3.50 D. at 100° and Em. at 10° right eye; M. 3 D. at 80° and H. 2 D. at 170° left eye.

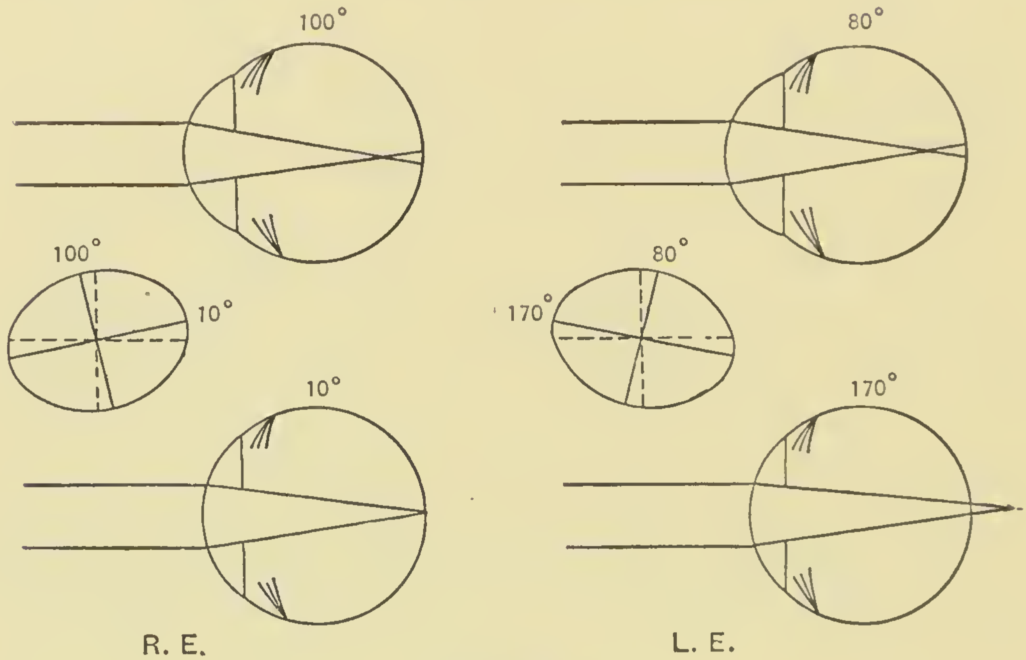


Fig. 83.

Second test: after using an astringent wash for a week, a second test was made.

Ophthalmometer. — Astigmatism with the rule, 3.50 D., axis 100° + or 10° – right eye; 5 D., axis 80° + or 170° – left eye.

The subjective test resulted in exactly the same glasses being accepted as at the first test, and they were ordered: —

– 3 D. cyl., 10° right eye;

+ 2 D. cyl., 80° – 2.50 D. cyl., 170° left eye.

Here, again, I did not convert the cross-cylinder into a sphero-cylinder, because the astigmatism was large in amount,

and because by actual trial of both the sphero-cylinders into which it could be transposed, the patient saw better with the cross-cylinder. Had I given a sphero-cylinder, it would have been a plus sphere with a minus cylinder, in order that the cylinder should correspond in character to the myopic cylinder in the opposite eye.

Case LXXVIII. *Mixed astigmatism with the rule left eye; Simple myopic astigmatism with the rule right eye; Asthenopia; Fitted to glasses without atropine, although the child was but eight years old; Relief with glasses.* — February 7, 1893, William G., aged eight years, is in good health, but has been troubled with headaches at school. He complains also of not being able to see the blackboard.

Ophthalmometer. — Astigmatism with the rule, 3.50 D., axis 105° + or 15° – right eye; 2.75 D., 75° + or 165° – left eye.

Test cards and trial lenses. —

R. V. = $\frac{20}{200}$ + : $\frac{20}{40}$ W. – 3 D. cyl., 15°.

L. V. = $\frac{20}{200}$ + : $\frac{20}{40}$ W. + 1.25 D. cyl., 75° – .75 D. cyl., 165°.

Ophthalmoscope. — M. 3.50 at 105° and Em. at 15° right eye; M. 1 D. at 75° and H. 1.50 D. at 165° left eye.

Second test: after using an astringent wash for a mild conjunctivitis, a second test for glasses was made. The test corresponded exactly in every way with the first test, and the glasses were ordered: —

– 3 D. cyl., 15° right eye;

+ 1.25 D. – 2 D. cyl., 165° left eye.

These glasses have been worn for more than five years, and with relief of headaches and other asthenopic symptoms.

The tender age of this patient, eight years, would seem to call for a mydriatic, especially when it was found that mixed astigmatism was present; nevertheless, he was fitted without

it. The axis of the glass corresponded exactly with the axis indicated by the ophthalmometer in each eye; but in the left eye .75 D. was deducted from the amount instead of the usual .50 D., as ordinarily in astigmatism with the rule.

The cross-cylinder was converted into a sphero-cylinder, a plus sphere with a minus cylinder, in order that the cylinder

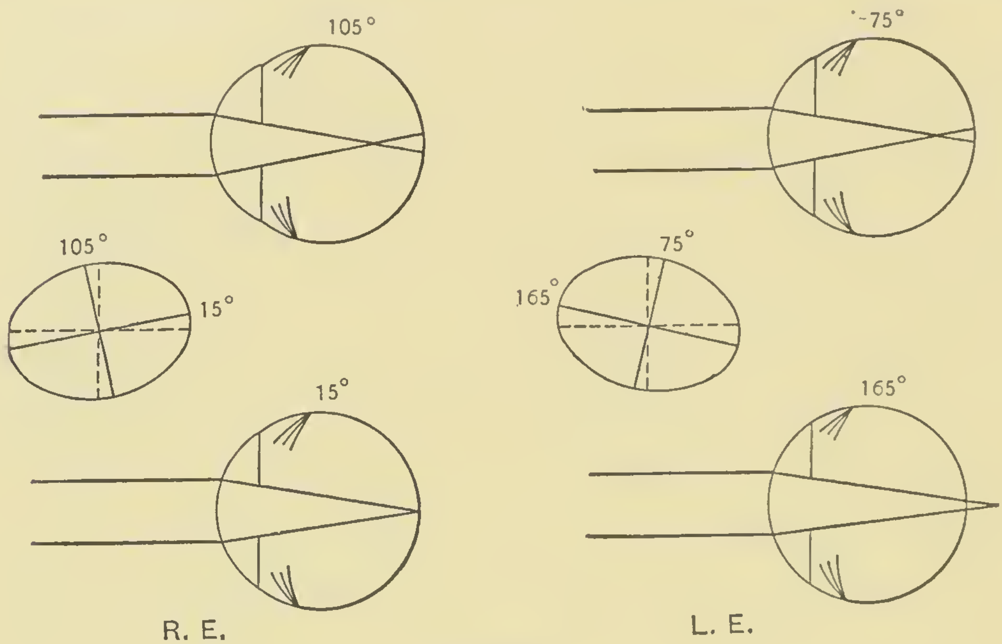


FIG. 84.

might correspond in axis and character with the simple myopic cylinder of the right eye. This made a slightly heavier glass than a sphero-cylinder with a minus sphere and a plus cylinder, but the importance of having both cylinders alike much outweighed the slight disadvantage in weight.

CASE LXXIX. *Mixed astigmatism with the rule right eye; Compound myopic astigmatism with the rule left eye: Constant pain in the eyes; Relief with glasses.*—February 23, 1892, Ella M., aged twenty-three years, in good health, came to the clinic of Drs. Roosa and Lewis at the Manhattan Eye and Ear Hospital, and was referred to me for treatment. She complained of severe pain in the eyes when she attempted close

work of any kind, and this has been so since a child. She is the only member of her family troubled with her eyes.

Ophthalmometer. — Astigmatism with the rule, 3 D., axis 75°+ or 165°− right eye; 3 D., axis 105°+ or 15°− left eye.

Test cards and trial lenses.—

R. V. = $\frac{7}{200}$: $\frac{20}{70}$ + W. + 1 D. cyl., 75° − 1.25 D. cyl., 165°.

L. V. = $\frac{7}{200}$: $\frac{20}{100}$ W. − 5 D. − 2.50 D. cyl., 15°.

Reads Jaeger No. 1 from 6 to 12 inches.

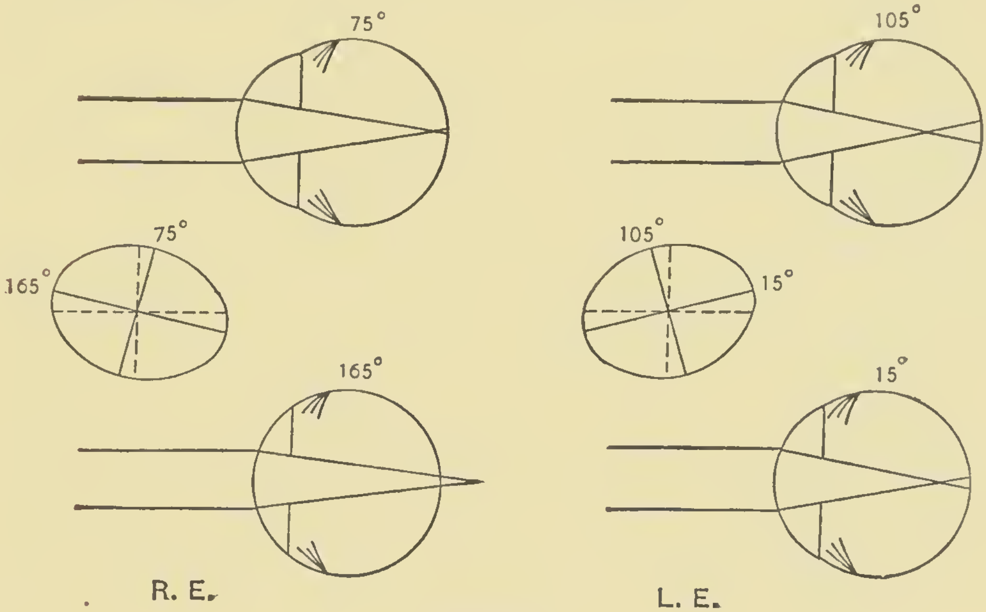


FIG. 85.

Ophthalmoscope. — M. 150 D. at 75° and H. 1.50 D. at 165° right eye; M. 7 D. at 105° and M. 3 D. at 15° left eye.

Second test: two days later the ophthalmometer gave the same reading as at first.

Test cards and trial lenses. —

R. V. = $\frac{7}{200}$: $\frac{20}{50}$ − W. + 1.25 D. cyl., 75° − 1 D. cyl., 165°.

L. V. = $\frac{20}{200}$: $\frac{20}{100}$ W. − 4 D. − 2 D. cyl., 15°.

This last glass was ordered, the cross-cylinder in the right eye being converted into a sphero-cylinder; a plus sphere with

a minus cylinder, in order that the cylinder should correspond in character and axis with the cylinder in the opposite eye. Ordered : —

+ 1.25 D. – 2.25 D. cyl., 165° right eye ;

– 4 D. – 2 D. cyl., 15° left eye.

These glasses gave immediate relief from her asthenopic symptoms. After a few weeks' time she dropped out from under observation.

In this case, as in the one reported immediately preceding it, the cross-cylinder was converted into a sphero-cylinder, plus sphere with a minus cylinder, rather than into a minus sphere and a plus cylinder. This made a little heavier glass, but the disadvantage was more than counterbalanced by having the cylinders correspond in character and axis. And by actual trial in the frames, before either glass was ordered, the patients preferred the plus sphere with a minus cylinder.

Case LXXX. *Mixed astigmatism with the rule in each eye, with the axes slanting 5° from the vertical and horizontal meridians in the same direction in each; Asthenopia; Relief with glasses.* — January 21, 1896, D. L. B., in excellent health, but has suffered a great deal with his eyes since a child at school. Headaches, blurring of the vision, burning of the eyelids and pains in the eyes, were some of the symptoms of which he complained. He has had numerous glasses prescribed, none of which proved satisfactory.

Ophthalmometer. — Astigmatism with the rule, 3 D., axis 95° + or 5° – in each eye.

Test cards and trial lenses. — The lines on the clock-dial were all seen about equally well with each eye, but indistinctly before the test was begun. When the plus cylinder was put on, the vertical lines showed the plainest, and when the final full amount of minus cylinder was added to the plus cylinder,

the horizontal lines also came out plainly, thus with the cross-cylinders all of the lines on the clock-dial were brought out plainly and evenly.

R. V. = $\frac{20}{200}$: $\frac{20}{20}$ W. + 1.50 D. cyl., 95° – 1.50 D. cyl., 5°.

L. V. = $\frac{20}{200}$: $\frac{20}{20}$ W. + 1.25 D. cyl., 95° – 1.25 D. cyl., 5°.

Reads Jaeger No. 1 from 3 to 16 inches.

Ophthalmoscope. — M. 1.50 D. at 95° and H. 1.50 D. at 5° in each eye.

Second test: one day later the ophthalmometer showed the same reading.

Test cards and trial lenses. —

R. V. = $\frac{20}{200}$: $\frac{20}{20}$ + W. + 1.50 D. cyl., 95° – 1.25 D. cyl., 5°.

L. V. = $\frac{20}{200}$: $\frac{20}{200}$ + W. + 1.50 D. cyl., 95° – 1.25 D. cyl., 5°.

A third test confirmed this second, and the glasses were ordered as cross-cylinders. Cross-cylinders were prescribed because they defined the letters better and felt easier to the eyes than either sphero-cylinder into which they could be converted. After wearing the glasses constantly for a week the doctor got relief from his asthenopic symptoms. I have had him under observation for more than two years, and he wears the same glasses with continued relief. It is comparatively a rare occurrence for the axes of an astigmatism in the two eyes to slant in the same direction from the horizontal and vertical meridians; and when it does happen, usually, the asthenopia is more marked in such cases than

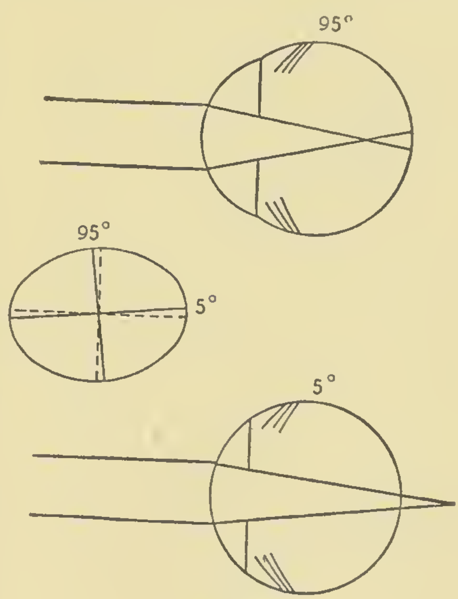


Fig. 86.

in those cases where the axes slant an equal number of degrees in opposite directions from the vertical and horizontal meridians. For example, say the axis in each eye slants 15° toward the temple from the vertical meridian, in which case, in hypermetropic astigmatism, the cylinder would be worn at 105° right eye, and at 75° left eye. In the present case both axes stand at 95°, slanting toward the temple in the right eye, and toward the nose in the left eye, or in the same direction.[1]

CASE LXXXI. *Mixed astigmatism against the rule right eye; No corneal astigmatism left eye, but the patient accepts a weak cylinder against the rule; Patient is very nervous; Marked asthenopia; Relief with glasses.* — June 27, 1894, Mary M., aged twenty-six years, in only fairly good health, and is very nervous. Her eyes have given her much trouble for the last four years, especially the right. She finds it almost impossible to use the eyes for close work of any kind. Not only do the eyes ache, but also her head, and often she becomes very nervous and irritable. Her mother died of consumption, but her father is still living and in good health. He wears very strong sphero-cylinders, while two brothers and a sister of the patient also wear cylindrical glasses.

Ophthalmometer. — Astigmatism against the rule, 3 D., axis 175° + or 85° – right eye. No corneal astigmatism left eye.

Test cards and trial lenses. —

$$\text{R. V.} = \tfrac{20}{200} : \tfrac{20}{30} \quad \text{W.} + 2.50\ \text{D. cyl., } 175°.$$

$$\text{L. V.} = \tfrac{20}{20} : \tfrac{20}{15} - \text{W.} + .25\ \text{D. cyl., } 15°.$$

Reads Jaeger No. 1 from 6 to 14 inches.

Ophthalmoscope. — M. 1 D. at 90° and H. 2 D. at 180° right eye; H. .50 D. left eye.

[1] For the relative position of the axes of astigmatic glasses, see Claiborne, *New York Med. Journal*, June 25, and July 2, 1892; Knapp, *Trans. Amer. Ophthal. Soc.*, Bd. Vol. VI, p. 308, 1892; and Snellen, Graefe's *Arch. Ophthal.*, Vol. XVI. No. 2, p. 200, 1869.

On account of a conjunctivitis an astringent wash was ordered, and after one week a second test was made. The ophthalmometer read the same as at the first test.

Test cards and trial lenses. —

R. V. = $\frac{20}{200}$: $\frac{20}{20}$ W. + 2.50 D. cyl., 175° – .50 D. cyl., 85°.

L. V. = $\frac{20}{20}$: $\frac{20}{15}$ W. + .25 D. cyl., 15°.

The ophthalmoscope agreed essentially with the first examination.

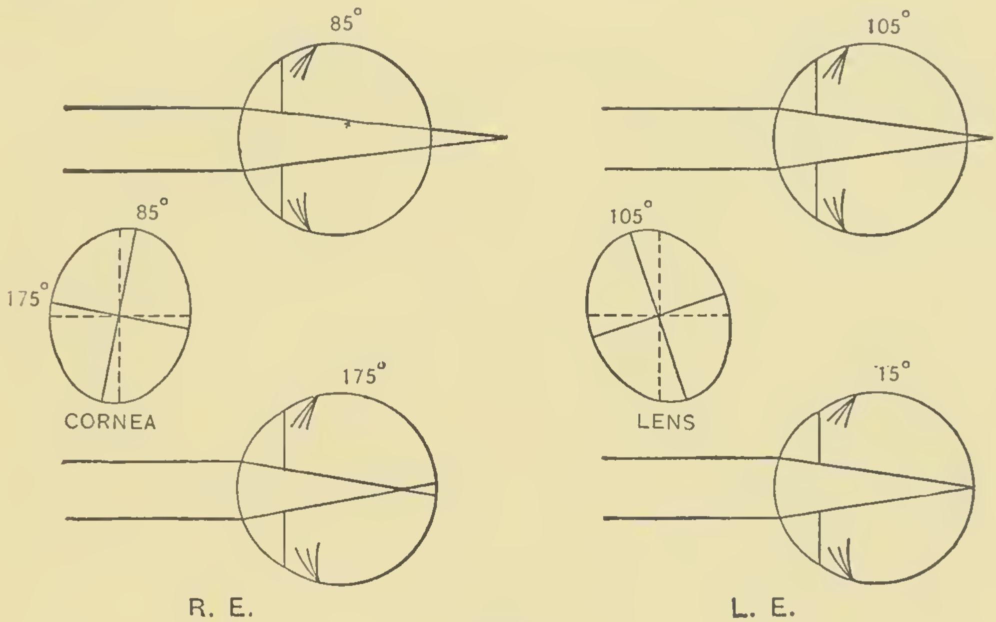


FIG. 87.

A third test was made, and as it agreed with the second, this last glass was ordered, a simple cylinder in the left eye, + .25 D. cyl., 15°, and a sphero-cylinder, – .50 D. + 3 D. cyl., 175° right eye. In converting the cross-cylinder into a sphero-cylinder I gave a minus sphere and a plus cylinder. This made a light glass, and at the same time the cylinder corresponded with the cylinder in the opposite eye. A plus sphere and a minus cylinder in this case is not to be thought of, because it would be heavy, and the cylinder would not correspond with the cylinder in the opposite eye.

In this case in the right eye the patient accepted all of the

astigmatism, no lenticular astigmatism being present. In the left there was no corneal astigmatism, but the patient accepted a weak plus cylinder against the rule.

It took the patient between three and four weeks to become accustomed to the glasses, but after that time she wore them with comfort and relief from asthenopia. At times she is nervous, but is much relieved in this respect. I saw her from time to time for a number of months, and the glasses continued to be satisfactory.

Case LXXXII. *Mixed astigmatism against the rule in each eye; Spasm of accommodation; Marked asthenopia; Relief with glasses.* — August 11, 1894, Jennie F., aged twenty-eight years, in good health, consults me on account of headaches and pains in the eyes. She has had more or less trouble with her eyes since childhood. There is a well-marked conjunctivitis present.

Ophthalmometer. — Astigmatism against the rule, 3 D., axis 155° + or 65° − right eye; 2 D., axis 175° + or 85° − left eye.

Test cards and trial lenses. —

R. V. = $\frac{20}{100}$: $\frac{20}{50}$ W. + 1.50 D. cyl., 155° − 1.50 D. cyl., 65°.

L. V. = $\frac{20}{50}$: $\frac{20}{30}$ W. + .75 D. cyl., 175° − .50 D. cyl., 85°.

Reads Jaeger No. 1 from 6 to 17 inches.

Ophthalmoscope. — M. 1.50 D. at 150° and H. 1.50 D. at 60° right eye; M. 1 D. at 180° and H. 1 D. at 90° left eye.

During the test, especially with the left eye, the patient would at one time accept a certain glass, then refuse it. Again, the vision at one moment would be very good, then the next moment poor. Thus, spasm of accommodation was clearly present. Examination of the muscles failed to show any insufficiencies. There was a well-marked conjunctivitis present, and this was treated for ten days, after which a second test was made.

Second test: the ophthalmometer gave the same reading in the right eye as at the first test; and the same amount of

astigmatism in the left eye as at first, but with the axes at exactly 180° and 90°.

Test cards and trial lenses. —

R. V. = $\frac{20}{100}$: $\frac{20}{50}$ W. + 1.50 D. cyl., 155° − 1.50 D. cyl., 65°.

L. V. = $\frac{20}{50}$: $\frac{20}{30}$ W. + 1.50 D. cyl., 180° − .50 D. cyl., 90°.

Ophthalmoscope. — Showed about the same condition as at the first test.

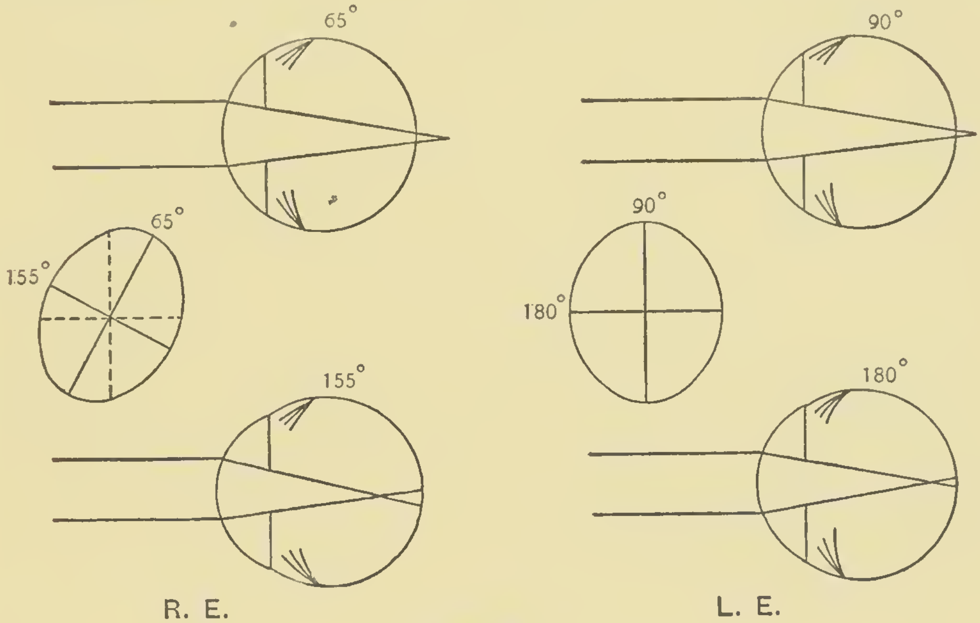


Fig. 88.

A third test was given which agreed with the second, and the glasses were ordered as sphero-cylinders, minus spheres with plus cylinders: —

− 1.50 D. + 3 D. cyl., 155° right eye;

− .50 D. + 2 D. cyl., 180° left eye.

In the left eye this was a lighter glass than a plus sphere with a minus cylinder, while in the right eye it made no difference.

Thus far, about four years, these glasses have been worn with comfort.

CASE LXXXIII. *Mixed astigmatism of small amount against the rule in each eye; Presbyopia; Asthenopia; Blepharitis; Relief of asthenopia and blepharitis with glasses.* — September 25, 1892, Henry C., aged forty-eight years, in good health, has been troubled with his eyes for five or six years when using them for close or prolonged work. The eyelids get red also if he persists in using the eyes, and, at times, headaches follow.

Ophthalmometer. — Astigmatism against the rule, .50 D., axis 10°+ or 100°− right eye; .50 D., axis 165°+ or 75°− left eye.

Test cards and trial lenses. —

R. V. = $\frac{20}{50}$: $\frac{20}{20}$ W. + .50 D. cyl., 10° − .25 D. cyl., 100°.

L. V. = $\frac{20}{40}$: $\frac{20}{20}$ W. + .50 D. cyl., 165° − .25 D. cyl., 75°.

Ophthalmoscope. — H. .50 D. in each eye. The myopic astigmatism was too small to estimate. The foci of the two chief meridians, according to the glasses accepted, can be seen from the following figure: —

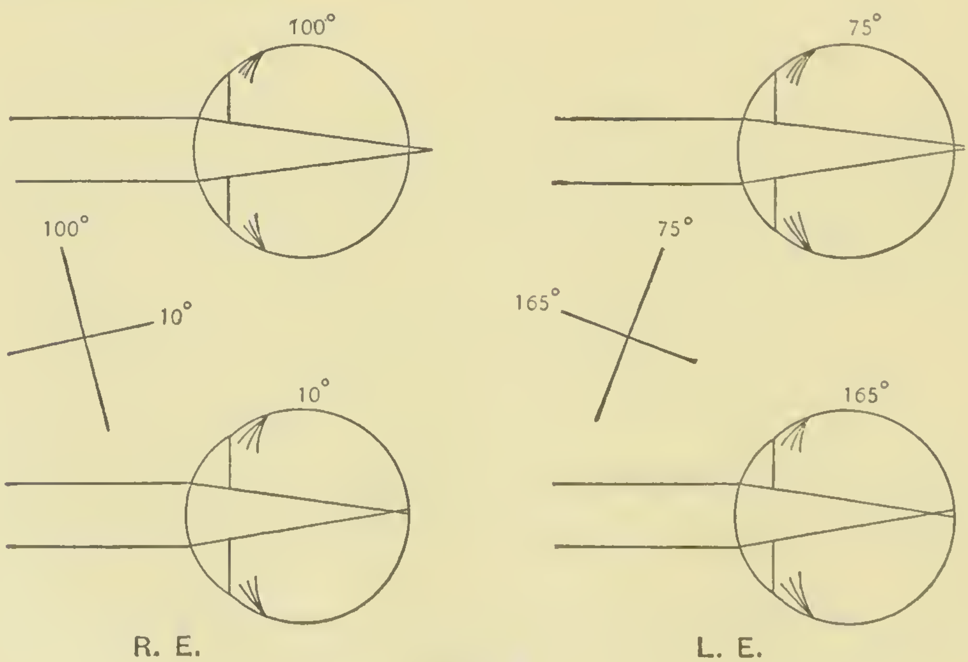


FIG. 89.

Two days later a second test was made, which corresponded in every particular with the first.

It will be noticed that the myopic portion of the glasses accepted by the patient is very small, only .25 D., and I find in the record of the case in my case-book the following note: "The − .25 D. cyl. when added to the + .50 D. cyl. increases the vision more than a line, or from $\frac{20}{30}$ − to $\frac{20}{20}$." Usually a .25 D. cylindrical glass does not improve vision so much, but in this case the astigmatism was against the rule and at an off axis (slanting), and that may account for its marked effect in the improvement of vision.

The patient would not wear glasses for the distance, though they improved the vision very much. Incidentally it may be remarked here, that many even intelligent people are content with poor distant vision, and will not wear glasses except for near work. Some, because they do not wish to be bothered with two pairs of glasses; some refusing to wear glasses on the street from vanity, perhaps.

On account of his presbyopia, he being forty-eight years of age, it was necessary to give him reading glasses. I allowed + 1.75 D. for his presbyopia. After having converted his distance cross-cylinders into sphero-cylinders, − .25 D. + .75 D. cyl., 10° right eye, and − .25 D. + .75 D. cyl., 165° left eye, it was an easy matter to add the + 1.75 D. sphere to them algebraically, which would give + 1.50 D. + .75 D. cyl., 10° right eye, + 1.50 D. + .75 D. cyl., 165° left eye.

The glasses were ordered, and have been worn for five years without change. They relieved him of his blepharitis entirely, and made close work comfortable, though for the last few months he has felt the want of a stronger glass.

A simple increase in the spherical part of his glass will, of course, be all that is necessary.

This case naturally brings up the question of transposition of glasses in mixed astigmatism made necessary by presbyopia.

I may say the transposition is made easier if the cross-cylinders are first converted into sphero-cylinders, as in the last case, then the presbyopic part added to them algebraically. Since this method of transposition has already been explained at length, under the lines given to myopia and myopic astigmatism, I shall not go here into the subject again except to give one or two examples.

In the last case reported here, for example, the change in the glasses made necessary by the presence of the 1.75 D. of presbyopia is made quite plain by a glance at Fig. 89 and the following diagram of cross-lines. Those who are in doubt as to the correctness of any combination of glasses they have made by the abstract algebraic equation, may resort to this method of drawing the sections of the two chief meridians of each eye with their foci, together with the simple cross-lines denoting those meridians, at the ends of which are marked the refractive power of each meridian in diopters. Then note the effect on the foci that any given amount of presbyopia will cause.

For instance, in Fig. 89, illustrating the last case, right eye, the meridian at 100° is hypermetropic by .50 D., and the focus is .50 D. back of the retina (+ .50 D. added to + 1.75 D. = + 2.25 D.); while the meridian at 10° is myopic by .25 D. with the focus to that extent in front of the retina, and the presbyopia of 1.75 D., for reading distance, would put the focus in this meridian but 1.50 D. back of the retina (− .25 D. added to + 1.75 D. = + 1.50 D.), that is, the myopia of .25 D. neutralizes that amount (.25 D.) of the presbyopia. From this it is quite evident, for reading purposes, the eye has been converted into a compound hypermetropic astigmatism, the meridian at 100° being 2.25 D. presbyopic, and that at 10°, 1.50 D. In order to correct this, a + 1.50 D. sphere, combined with + .75 D. cyl., 10°, is necessary. This, in fact, was ordered. Like changes took place in the left eye, as will be seen by looking at Figs. 89 and 90.

I have presented these cases of mixed astigmatism in their various forms at some length, for the purpose of showing that even these difficult cases may be fitted, in most instances, without the aid of a mydriatic. The cases here presented are not selected ones. The indications for the use of a mydriatic in these cases are exactly the same as in others of refractive error, to wit, lack of uniformity in tests, spasm of accommodation, and so forth.

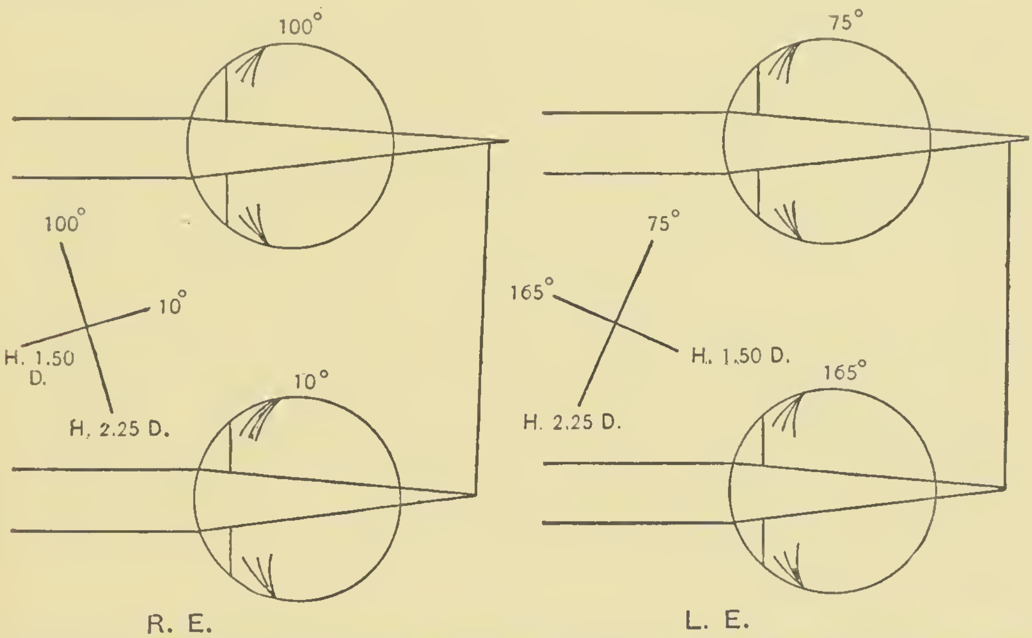


FIG. 90. — Showing the effect of a presbyopia of 1.75 D. on the near-point in the case just reported. See Fig. 89 for the distance focus.

The amblyopia present in most cases of mixed astigmatism is the one great stumbling-block for many observers, and serves to induce them to use a mydriatic whether there are any other indications for its use or not. In regard to amblyopia, a certain amount of it is to be looked for in most cases of astigmatism, especially if the astigmatism is large in amount; consequently, we should not expect to bring vision up to normal, $\frac{20}{20}$, or nearly so, in all cases. If the patient accepts the same glasses on two or three successive tests, and they correspond with the objective tests, we may give the glasses without hesitation.

In order to make myself doubly sure that I am not giving

too weak plus, and too strong minus, cylinders in these cases, after I have tested each eye separately, I then put the glasses on as accepted and uncover both eyes. With both eyes uncovered, I increase the plus cylinder .25 D. in strength, to see if the vision can be improved by the change, and I also diminish the minus cylinders .25 D. to find if vision can be improved.

Another point I wish to insist upon is, that the test should be conducted methodically and quickly, and the patient kept not over thirty minutes in any one test. Have the patient come back two, three, or four times, if necessary, but do not worry him for an hour or two at a time in the vain attempt to get perfect vision. Because: first, as asserted above, many times perfect vision is not to be had, whatever means, mydriatics or what not, are employed to secure it; second, if the test is very prolonged, the patient grows tired, becomes confused in his replies, spasm of accommodation is incited, and the observer himself gets disgusted and orders a mydriatic, not knowing what else to do, perhaps. If after two tests, of not more than thirty minutes' duration, the tests do not approximately agree, and there is a tendency to, or an actual, spasm of accommodation, I then order a mydriatic, but not until then.

In all of these cases the routine method of beginning the test with weak plus glasses and gradually increasing them in strength until the vision begins to be made worse, and then trying minus cylinders at right angles to the plus as long as they improve vision, is followed. The test should never under any circumstances be begun with minus cylinders, because if it is, the patient, nine times out of ten, will accept the full amount of the astigmatism in minus cylinders. While these glasses might be worn for a few weeks or months even with comparative comfort, yet after a short time they would have to be changed, as the patient would gradually relax his accommodation. Therefore, the necessity of avoiding the mistake of beginning the test incorrectly is apparent.

CHAPTER VIII

IRREGULAR ASTIGMATISM — CONICAL CORNEA — HYPERBOLIC LENSES — CONTACT LENSES — ILLUSTRATIVE CASES

Before the days of the perfected ophthalmometer, in no class of cases did we have more difficulty in fitting glasses, even with tolerable satisfaction, than in those with irregular curvature of the cornea, due to opacities, conical cornea, and so forth. Thanks to the efforts of Javal and Schiötz, who made the ophthalmometer a practical office instrument, we now sometimes score our greatest triumphs in just such cases. The disk of Placido, attached to the 1889 model of the ophthalmometer, aids greatly in detecting irregularity of surface on the cornea; and, for this one reason, if for no other, should not be removed from the instrument, as suggested and actually done by some of my American confrères. In cases of conical cornea, especially are the concentric circles on the disk and the disk itself of marked service in giving us the general shape of the cornea and the topography of the cornea at any special point on it. Furthermore, by having the patient look at a point a certain number of degrees from the center of the disk, as marked on the circles drawn on the disk in conjunction with the radii drawn from the center of the disk, we can measure the radius of curvature of the cornea in its two chief meridians at that number of degrees from its center, but on the opposite side from which the patient is looking. For example, if we cause the patient to look directly upward at a point of crossing of the circle marked 20°, and the radiating line extending directly upward, we measure a point on the cornea

20° below its center. And so for any other point on the cornea.

Again, the circular lines on the disk give us important information as to the condition of the surface of the cornea, not only as to irregular astigmatism, as manifested by irregularity and distortion of these circular lines, but as to the presence of regular astigmatism, when present in large amount with it, as manifested by an elongation of these circles in the direction of the meridian with the longest radius of curvature. I may say in this place that Reid's ophthalmometer is a most valuable little instrument in detecting irregular astigmatism and conical cornea of small amount, and for the following reason: In Reid's instrument, the two images looked at are two circles, or, rather, one circle doubled by means of a prism, and the least irregularity of the surface of the cornea is quickly detected by these circles becoming irregular in outline. At the same time, if regular astigmatism is present, it indicates it by the circles becoming elliptical in shape. In conical cornea of moderate amount, if a suitable prism is put in the telescope of the instrument, this instrument is very valuable. The reader is referred to the Appendix of this book for a description of the instrument and its use.

Again, in the Javal-Schiötz instrument, the images of the mires themselves are of service in detecting irregular astigmatism, on the same plan as Wecker's squares, that is, by their distortion and irregularity of outline when irregular astigmatism is present. It is also shown when there is no position on the cornea where the lines dividing them through the center can be made to form one continuous straight line. However, if regular astigmatism is present in addition to the irregular, there are two positions on the cornea at which these lines become more nearly straight than elsewhere, thus indicating the axis of the regular astigmatism.

So delicate a test is this distortion of the images of the

mires, that the slightest irregularity of the surface of the cornea is detected. This leads to a close inspection of the cornea by oblique illumination, and the detection of minute opacities, which otherwise would be overlooked at times.

The ophthalmometer, together with the disk of Placido, is also of the greatest value in finding the most regular part of a cornea affected with central opacity or leucoma, or, in case of conical cornea, behind which to perform an iridectomy for visual purposes. It is of the utmost necessity to place the iridectomy behind the clearest and most regular portion of the cornea in such cases. Not only is the ophthalmometer of value in detecting this best place on the cornea, but it will detect and measure any regular astigmatism present at such place. For example, if in a given case we have found the portion of the cornea directly inward from the center (right eye) to be the clearest, and have accordingly performed an iridectomy for visual purposes, and later wish to fit the eye for glasses. To measure this portion of the cornea, we cause the patient to turn the eye directly outward about 15° (letting him look at the point of crossing of the 15° circle and the horizontal radiating line), and ascertain the regular part of the astigmatism. In this way, the fitting of the correct and best glass is greatly facilitated. Indeed, what was at one time a most tedious, and, in many instances, a hopeless task — the fitting of glasses in irregular astigmatism — is reduced, by the aid of the ophthalmometer and Placido's disk, to a scientific and definite result.

Some concrete cases will illustrate the above points.

Case LXXXIV. *Slight irregular astigmatism due to opacities of the cornea; Regular astigmatism; Amblyopia; Asthenopia.* — January 4, 1898, Pauline G., aged eleven years, in good general health, came to the clinic of Drs. Lewis and Van Fleet, at the Manhattan Eye and Ear Hospital, and was assigned to me for treatment. The patient's mother says that her child's

eyes were slightly inflamed when a baby. She has complained of poor and painful vision since she entered school. The patient has always appeared to be near-sighted.

On looking at this patient's eyes without oblique illumination, no opacities can be seen, and nothing of a peculiar character appears to the observer.

Ophthalmometer. — Regular astigmatism with the rule, 1.50 D., axis 90° + or 180° − right eye; 1.25 D., axis 75° + or 165° − left eye. Irregular astigmatism in each eye, as made manifest by dimness and irregularity of the outlines of the images of the mires, and by the line dividing the mires into halves (guide-lines) not being clear-cut in any position, but dim and wavy in appearance. The concentric circles on the Placido disk were dim and irregular in outline also.

Test cards and trial lenses. —

R. V. = $\frac{20}{50}$: $\frac{20}{30}$ W. + 1 D. cyl., 90°.
L. V. = $\frac{20}{40}$: $\frac{20}{30}$ − W. + .75 D. cyl., 75°.

Reads Jaeger No. 1 from 3 to 15 inches. She has a desire to hold the print too close.

Ophthalmoscope. — Em. at 90° and H. 1 D. at 180° right eye; Em. at 75° and H. .50 D. at 165° left eye. Oblique illumination of the corneæ showed opacities of a diffuse nature in each.

Second test: four days after the first test a second one was made, and as the patient accepted exactly the same glasses as at first, they were ordered. When last seen, about two months after being fitted, the glasses were giving satisfaction, and the patient was able to pursue her studies with comfort.

CASE LXXXV. *Irregular astigmatism associated with a large amount of regular astigmatism following perforating ulcer of the cornea; Marked decrease both of the irregular and regular astigmatism, with attendant increase of vision in one year's time.* — This is a most interesting case, because of the changes that

occurred in the shape of the cornea after the ulcer had healed, which were studied by means of the ophthalmometer, and noted for a long period. I give a brief history of the case : —

Mr. D. L., aged thirty-two years, first came under my care September 13, 1893, for treatment for ulcerative keratitis with hypopion, which was due to an injury from a piece of iron from a chisel. A large sloughing ulcer covered the lower half of the cornea, extending up almost to the center of the cornea, and the anterior chamber was half full of pus. With paracentesis, atropine, hot water and bandage, the patient recovered in two weeks' time, but not without the ulcer perforating. Fortunately, the pupil was well dilated before perforation occurred, so there was no prolapse of iris, and the pupil was circular, central, and active after the effects of atropine wore off. At time of discharge of the patient from the hospital he could see the hand at 2 feet distance only.

November 4, a little over a month after his discharge from the hospital, I examined his eye carefully with the ophthalmometer and with the lenses. I may say at this time that the eye was perfectly white, the pupil central and active, and the lower outer quadrant of the cornea had a dense opacity covering it, while the lower inner quadrant had a diffuse opacity extending to the level of the lower edge of the pupil. The patient stated that his vision was much improved.

Ophthalmometer. — The right eye had .50 D. astigmatism with the rule, axis 120° + or 30° − ; left eye showed marked irregular astigmatism, with a large amount of regular astigmatism with the rule, 12 D., axis 45° + or 135° −.

Test cards and trial lenses. —

R. V. = $\frac{20}{20}$: not improved.

L. V. = $\frac{10}{200}$: $\frac{20}{100}$ W. − 9 D. cyl., 135°.

Ophthalmoscope. — H. 1 D. right eye ; the fundus in the left eye is seen indistinctly, the outline of the disk is irregular,

and the blood vessels distorted and partly seen; that is, a portion of a vessel would be seen well one moment and lost the next, if either the ophthalmoscope or patient's head moved.

February 18, 1894, three months later, a second test was made.

Ophthalmometer. — The astigmatism was the same as at the first test in the right eye; irregular astigmatism, not so marked as before, and regular astigmatism against the rule, 8.50 D., axis 15° + or 105° − left eye.

Test cards and trial lenses. —

R. V. = $\frac{20}{20}$ + : not improved.

L. V. = $\frac{20}{200}$: $\frac{20}{100}$ + W. − 7.50 D. cyl., 105°.

November 9, 1894, a little over a year after the first examination, the following remarkable improvement was noted: —

Ophthalmometer. — Test the same in the right eye as before; moderate amount of irregular astigmatism with regular astigmatism with the rule (as on the first test), 3 D., axis 45° + or 135° − left eye.

Test cards and trial lenses. —

R. V. = $\frac{20}{20}$ + : not improved.

L. V. = $\frac{20}{100}$ − : $\frac{20}{70}$ W. − 3 D. cyl., 135°.

I had this patient under observation for about fifteen months. The most interesting feature of the case was the remarkable change in the character and amount of the astigmatism in the left eye. Twelve diopters of regular astigmatism with the rule associated with marked irregular astigmatism changed in a little over three months' time to 8.50 D. *against the rule*; and then in nine months the regular astigmatism diminished to 3 D. *with the rule*, and back to the same axis exactly as at first, and with marked improvement in the irregular astigmatism.

Without the aid of the ophthalmometer, it would have been almost impossible to note these changes and to make the correct

tests for vision. With it, it was comparatively easy, and the fact was demonstrated to him, that he had useful vision in the left eye, should he lose the right. This was naturally a source of great comfort to him.

CASE LXXXVI. *Irregular astigmatism associated with regular astigmatism against the rule right eye; Regular astigmatism against the rule left eye; Asthenopia; Relief with glasses.* — June 1, 1894, Mrs. L. T. S., aged forty-one years, is in fairly good general health, has had more or less trouble with her eyes for the last four years. Twelve years ago she was very much run down in health and could not use her eyes for close work for about two months. She thinks her eyes were weakened when a child, from an attack of measles. She has headaches now and pain in the eyes if she sews or reads.

Ophthalmometer. — Irregular astigmatism to a moderate degree with regular astigmatism against the rule, .50 D., axis 135° + or 45° – right eye; regular astigmatism against the rule, 3 D., axis 150° + or 60° – left eye.

Test cards and trial lenses. —

R. V. = $\frac{20}{70}$: $\frac{20}{40}$ – W. + 1 D. + .50 D. cyl., 135°.

L. V. = $\frac{20}{50}$: $\frac{20}{20}$ – W. + 2.75 D. cyl., 150°.

Reads Jaeger No. 1 from 7 to 16 inches.

Ophthalmoscope. — H. 2 D. at 45° and H. 1 D. at 135° right eye; H. 3 D. at 60° and Em. at 150° left eye. The fundus in the right eye was made somewhat indistinct by the faint corneal opacities, and the estimation of the error of refraction by the ophthalmoscope made doubtful.

Second test: two days later, a second test was made in which the ophthalmometer gave the same readings as at the first test.

Test cards and trial lenses. —

R. V. = $\frac{20}{70}$: $\frac{20}{40}$ W. + 1.25 D. + .75 D. cyl., 135°.

L. V. = $\frac{20}{50}$: $\frac{20}{20}$ – W. + 2.75 D. cyl., 150°.

This last glass was ordered, and gave her almost entire relief from her headaches.

The ophthalmometer was of especial value in this case in ascertaining the regular astigmatism present in the right eye, in conjunction with the irregular. Although the vision could not be brought up to the normal, as in the other eye which had much more regular astigmatism, it was greatly improved. The amblyopia in the right eye in this case can be accounted for in the main by the presence of faint opacities in the cornea, as the fundus of the eye was normal. It would have been folly to put atropine in such an eye, as the patient was over forty years of age.

CASE LXXXVII. *Irregular astigmatism in each eye; Large amount of regular astigmatism in each eye of the mixed variety; Severe asthenopia; Vision considerably improved and asthenopia relieved with the correcting glasses.* — January 28, 1894, Bertha G., aged twenty-one years, general health only moderately good, has had trouble with her eyes since a child, following an attack of measles. Three years ago had an attack of *la grippe*, which weakened her general strength very much, and since then she has had recurrent ulcers on the margins of the cornea in each eye.

At present each cornea at its periphery has a row of dense opacities, about three millimeters in diameter, separated by a small portion of clear cornea from each other, encircling it entirely. The opacities look very much like the opacities left on the cornea at times after an episcleritis. The center of each cornea is clear, but the healing of each ulcer seems to have put some uneven tension on the cornea, and, as a consequence, in the left eye especially, even this clear portion of the cornea is uneven. This fact is made quite plain by the distortion of the images of the mires on the ophthalmometer, also by the circles on Placido's disk.

The patient has been wearing glasses for two years, but they do not relieve the pain in her eyes and head.

Ophthalmometer. — Irregular astigmatism, and regular astigmatism against the rule, 3 D., axis 135° + or 45° – right eye. Irregular astigmatism, and regular astigmatism with the rule, 5 D., axis 75° + or 165° – left eye.

Test cards and trial lenses. —

R. V. = $\frac{20}{50}$: $\frac{20}{40}$ W. + 2.75 D. cyl., 135°.

L. V. = $\frac{20}{70}$: $\frac{20}{50}$ W. + 3.25 D. cyl., 75° – .75 D. cyl., 165°.

Reads Jaeger No. 1 from 5 to 15 inches.

Ophthalmoscope. — H. 2 D. at 45° and M. 1 D. at 135° right eye; H. 3 D. at 165° and M. 1 D. at 75° left eye. The fundus of each eye was somewhat hazy and indistinct, and the measurement with the ophthalmoscope doubtful.

Second test: one day later a second test was made.

Ophthalmometer. — Irregular astigmatism in both. Regular astigmatism against the rule, 2.75 D., axis 140° + or 50° – right eye; regular astigmatism with the rule, 4.50 D., axis 75° + or 165° – left eye.

Test cards and trial lenses. —

R. V. $\frac{20}{50}$: $\frac{20}{20}$ – W. + 2 D. cyl., 140° – .75 D. cyl., 50°.

L. V. $\frac{20}{70}$: $\frac{20}{50}$ W. + 3 D. cyl., 75° – .75 D. cyl., 165°.

Two days later a third test was given, which corresponded with the second, and the glasses were ordered in cross-cylinders. These glasses were worn constantly, and proved very satisfactory.

The patient was wearing, when she came under my care, + 50 D. sphere right eye, and + 2 D. cyl., 75° left eye, which helped the right eye not in the least and the left eye but little. With the aid of the ophthalmometer and three tests, without atropine, she was fitted with comfortable and much appreciated glasses. She continued under observation for about six months' time, and the glasses were still satisfactory at the end of that time.

Case LXXXVIII. *Regular astigmatism with the rule right eye; Irregular astigmatism associated with a large amount of regular astigmatism with the rule of a mixed nature left eye; Asthenopia.* — February 3, 1893, Katie B., aged sixteen years, in good general health, has been troubled with weak eyes ever since a child. She had ulcers on the left eye when a child, and has had calomel dusted into the eye for a long time, but without much benefit to vision or clearing up of the opacities.

Ophthalmometer. — Astigmatism with the rule, 1 D., axis 90° + or 180° − right eye. Irregular astigmatism, also regular astigmatism with the rule, 4.50 D., axis 90° + or 180° − left eye.

Test cards and trial lenses. —

R. V. = $\frac{20}{20}$: $\frac{20}{15}$ W. + .75 D. + .25 D. cyl., 90°.

L. V. = $\frac{20}{200}$: $\frac{20}{100}$ W. + 1.50 D. cyl., 90° − 2 D. cyl., 180°.

Reads Jaeger No. 1 from 4 to 14 inches.

Ophthalmoscope. — H. 1.50 D. right eye; M. 2 D. at 90° and H. 2 D. at 180° left eye. The fundus in the left eye is indistinct and the error of refraction difficult to estimate.

A second test resulted in the patient accepting exactly the same glasses as at the first test, and they were ordered. The diffuse opacities on the cornea in the left eye prevented much improvement in the vision, even after the greater part of the astigmatism was corrected, but, as the patient accepted exactly the same glasses on two successive tests, they were ordered. These glasses gave relief from her painful vision for two months, since which time she has not been under observation.

Case LXXXIX. *Marked irregular astigmatism, with a large amount of regular astigmatism with the rule right eye; Regular astigmatism against the rule left eye; Asthenopia only to a limited degree.* — February 22, 1896, P. T. Q., aged twenty-six years, in first-class health, has always seen poorly, comes for a pair of glasses. When a child he had an ulcer on the right eye.

He does not complain of much pain in the eyes or head, but chiefly of poor vision.

Ophthalmometer. — Irregular astigmatism, also regular astigmatism against the rule, 5 D., axis 165° + or 75° − right eye; regular astigmatism against the rule, 1 D., axis 180° + or 90° − left eye.

Test cards and trial lenses. —

$$\text{R. V.} = \tfrac{7}{200} : \tfrac{20}{100}\ \text{W.} - 2\ \text{D.} - 5\ \text{D. cyl., } 75°.$$

$$\text{L. V.} = \tfrac{20}{200} : \tfrac{20}{40}\ \text{W.} - 1.50\ \text{D. cyl., } 90°.$$

Reads Jaegar No. 1 from 5 to 12 inches.

Ophthalmoscope. — M. 3 D. at 75° and 8 D. at 165° right eye; Em. at 90° and M. 2 D. at 180° left eye. A large opacity occupied the lower half of the right cornea, extending up to a level with the lower edge of the pupil.

A second test corresponded with the first, and the glasses were ordered. They were worn with comfort, and with great improvement in vision.

CASE XC. *Irregular astigmatism very slight, associated with mixed astigmatism of large amount against the rule left eye; Emmetropia right eye.* — June 3, 1896, C. J. S., aged twenty-seven years, in perfect general health, consulted me on account of poor vision in his left eye. Five years ago he had gonorrhœal ophthalmia in the left eye, with perforating ulcer of the cornea. There is a small dense opacity at the lower portion of the cornea, but with no synechia, however, between the iris and cornea, and the pupil is central, circular, and active. He was fitted to glasses shortly after his recovery from the ophthalmia, which have given satisfaction until the last two months. The left eye has pained him after doing close work of any kind for the last two months.

Ophthalmometer. — Regular astigmatism with the rule, .50 D., axis 90° + or 180° − right eye; slight irregular astig-

matism, also regular astigmatism against the rule, 4 D., axis 140° + or 50° − left eye.

Test cards and trial lenses. —

R. V. = $\frac{20}{15}$ − : not improved.

L. V. = $\frac{20}{200}$ − : $\frac{20}{20}$ − W. + 2 D. cyl., 140° − 1.50 D. cyl., 50°.

Reads Jaeger No. 1 from 6 to 21 inches.

Ophthalmoscope. — H. .50 D. right eye; H. 2 D. at 50° and M. 2 D. at 140° left eye.

Two days later, a second test was made, and the patient accepted exactly the same glass as at the first test. Ordered a plain glass right, and + 2 D. cyl., 140° − 1.50 D. cyl., 50° left eye. The glasses gave him complete relief from pain in the eye.

I kept the patient under observation for more than two years, and at the end of that time he continued to wear the same glass with comfort.

The irregular astigmatism was but slight in this case, yet enough to be detected by the ophthalmometer, and this could be done especially when the arc was in the vertical meridian. The fact, however, of the cornea being perfectly clear at the point intersected by the visual line, allowed good vision when the regular part of the astigmatism was corrected. The amount of amblyopia that is usually present in such cases was not present here. I think this can be accounted for by the fact that this astigmatism was acquired, that is, it was produced by a contraction of a scar on the lower half of the cornea. The perceptive part of the eye was not damaged by the ophthalmia, as proved by the fact that the eye had almost perfect vision when the astigmatism was corrected.

Case XCI. *Irregular astigmatism associated with a large amount of regular astigmatism with the rule in each eye; Antimetropia; Trichiasis; Asthenopia; Relief with operation and glasses.* — September 24, 1896, W. B. L., aged twenty-nine years,

in good health, has been troubled with his eyes since fourteen years of age. This trouble began with inflammation of the lids, followed by ulcers on the eyes, and for the last four years he has had "wild hairs" on the left eyelids, which hairs he had pulled out from time to time.

On account of the trichiasis and slight entropion of the left upper lid, an entropion operation was performed on this lid before glasses were fitted. Two weeks after the operation the first test was made.

Ophthalmometer. — Astigmatism with the rule, 6 D., 75° + or 165° −, with irregular astigmatism right eye; astigmatism with the rule, 6 D., 80° + or 170° −, with irregular astigmatism left eye. Although the irregular astigmatism was made quite manifest by the distortion of the images of the mires, and by the wavy outlines of the line dividing the mires, there was a large amount of regular astigmatism present which could be measured with reasonable accuracy.

Test cards and trial lenses. —

R. V. = $\frac{10}{200}$: $\frac{20}{50}$ W − 3.50 D. − 4.50 D. cyl., 170°.

L. V. = $\frac{10}{200}$: $\frac{20}{50}$ W + 4.50 D. cyl., 80°.

Reads Jaeger No. 1 at 8 inches.

Ophthalmoscope. — M. 10 D. at 90° and 5 D. at 180° right eye; Em. at 90° and H. 5 D. at 180° left eye. There are a few scattering fine opacities on the right cornea; on the left cornea, especially at the upper margin, the opacities are more numerous, giving a faint hazy view to the fundus.

Four days later, a second test was made, when the patient accepted the same glasses as at the first test in the left eye, and the same cylinder in the right, but with a half diopter weaker sphere. Ordered: —

− 4.50 D. cyl., 170° right eye;

+ 4.50 D. cyl., 80° left eye.

This patient was kept under observation for fifteen months, and the glasses were at that time still worn with satisfaction and relief from his asthenopic symptoms.

Considering the fact that this was a case of antimetropia, that a moderate degree of irregular astigmatism was present in each eye, together with a large amount of regular astigmatism, the result was gratifying. The axis of the cylinder in the right eye did not agree with the reading of the ophthalmometer by 5°, and 1.50 D. of astigmatism had to be deducted from the reading of the instrument in each eye, instead of the usual .50 D. as is usually the case when the astigmatism is with the rule.

Case XCII. *Irregular astigmatism; Regular astigmatism; Blepharitis marginalis; Partial relief with glasses.* — February 4, 1896, Mrs. L. G. F., aged twenty-six years, in poor general health, has had weak eyes since a small child, she says following an attack of measles. She has never worn glasses. Two years ago she had recurrent ulcers on the left eye; and in the last few months has had the same trouble again, and her family physician, Dr. J. T. Wheeler, referred her to me on that account.

On the right eye, just below the center of the cornea on a level with the lower edge of the pupil, is a small dense opacity. On the left cornea near its center are four small facets; and on the lower outer quadrant an oval-shaped opacity, about 3 mm. long and 2 mm. broad. The edges of the lids are red, and there are some scales on them. She has an herpetic eruption on the hands, and she says when the hands are bad the eyes are better, and *vice versa*. I may add that she is a very nervous woman.

Ophthalmometer. — Irregular astigmatism slight, with regular astigmatism with the rule, 3 D., axis 105°+ or 15°− right eye; irregular astigmatism marked, with regular astigmatism with the rule, 3 D., axis 105°+ or 15°− left eye.

Test cards and trial lenses. —

R. V. = $\frac{8}{200}$: $\frac{20}{50}$ W. – 6 D. – 1 D. cyl., 15°.

L. V. = $\frac{6}{200}$: $\frac{20}{50}$ W. – 5 D. – 2 D. cyl., 15°.

Reads Jaeger No. 1 at $6\frac{1}{2}$ inches.

Ophthalmoscope. — M. 7 D. each. Slight posterior staphyloma in each eye to the temporal side of the disk.

A wash of boracic acid was given, also yellow oxide of mercury ointment (gr. i to ℥i) was ordered. After ten days' treatment a second test was given.

Second test: the ophthalmometer gave the same reading as before.

Test cards and trial lenses. —

R. V. = $\frac{10}{200}$: $\frac{20}{40}$ W. – 5 D. – 2 D. cyl., 15°.

L. V. = $\frac{8}{200}$: $\frac{20}{40}$ W. – 5 D. – 2 D. cyl., 15°.

Reads Jaeger No. 1 at 7 inches.

These last glasses, with .50 D. deducted from the spherical portion, were ordered. They gave the patient much relief from the strained feeling in the eyes and made her much more comfortable. After wearing them for two years I saw her again. In the last month before the second visit to me, she had had a small ulcer on the left eye. This reduced the vision somewhat in that eye, but no glass could improve the vision more than the one she had on, so no change at all was made in the glasses. The right eye remained as when I first saw her. Her general condition was somewhat improved, but was still very poor.

CASE XCIII. *Irregular astigmatism associated with compound myopic astigmatism against the rule left eye; Compound myopic astigmatism against the rule right eye; Asthenopia; Relief with glasses.* — November 6, 1897, S. M. B., aged sixteen years, in good general health, consults me on account of poor

vision and pain in the left eye. She had an ulcer on the left eye when eight years of age which perforated, and since then has seen poorly in that eye. She does not see the blackboard well at school.

She has worn glasses (– .50 D. sphere) on each eye for the last six months, but with little improvement in vision.

Ophthalmometer. — Astigmatism with the rule, .50 D., axis 90° + or 180° – right eye; irregular astigmatism, with regular astigmatism against the rule, 2.50 D., axis 30° + or 120° – left eye.

Test cards and trial lenses. —

R. V. = $\frac{20}{50}$: $\frac{20}{20}$ – W. – 1.25 D.

L. V. = $\frac{10}{200}$: $\frac{20}{70}$ W. – 4 D. – 2 D. cyl., 120°.

Reads Jaeger No. 1 from 4 to 15 inches.

Ophthalmoscope. — M. 1 D. right eye; M. 4 D. at 120° and 6.50 D. at 30° left eye. There is an opacity on the left cornea about 3 mm. in diameter, with the lower pupilary margin of the iris incarcerated into it. This opacity is situated halfway between the center of the cornea and its lower margin in the vertical meridian. The fundus in each eye is normal.

Second test: three days later, a second test was made.

Ophthalmometer. — Astigmatism with the rule, .25 D., axis 90° + or 180° – right eye; the same reading in the left eye as at the first test.

Test cards and trial lenses. —

R. V. = $\frac{20}{50}$: $\frac{20}{20}$ W. – .75 D. – .25 D. cyl., 90°.

L. V. = $\frac{10}{100}$: $\frac{20}{70}$ W. – 3.50 D. – 2 D. cyl., 120°.

Reads Jaeger No. 1 from 4 to 15 inches.

The ophthalmoscope gave the same result as at the first test.

These last glasses were ordered to be worn constantly. They gave immediate relief and were worn for a little over a year with comfort, but at the end of that time, November 26,

1898, she came again, complaining of some pain in the eyes, and also of burning and itching of the eyelids. After treating the eyelids for a week, I again tested the eyes with the following result: —

Ophthalmometer. — Astigmatism with the rule, .25 D., axis 90° + or 180° – right eye; irregular astigmatism and regular astigmatism with the rule, 2.50 D., axis 45° + or 135° – left eye.

Test cards and trial lenses. —

R. V. = $\frac{20}{50}$: $\frac{20}{20}$ W. – 1 D. – .50 D. cyl., 90°.

L. V. = $\frac{10}{200}$: $\frac{20}{70}$ W. – 3.50 D. – 1.50 D. cyl., 135°.

Reads Jaeger No. 1 from 4 to 16 inches.

Ophthalmoscope. — M. 1.50 D. right eye; M. 4 D. at 135° and M. 6 D. at 45° left eye. Normal fundus in each eye.

On a second test, the patient accepted exactly the same glasses, and they were ordered. For the two months that she has worn them they have given relief from the pain in the eyes.

Conical Cornea

In cases of conical cornea, there is always more or less irregular astigmatism; and, while the ophthalmometer is not capable of measuring this astigmatism with exactness, either as to the amount or the axis, yet with it we are enabled to closely approximate them. Even in extreme cases, when the center of the cornea is so pointed, or occupied by an opacity, that it is no longer fit for visual purposes, by the help of the ophthalmometer and Placido's disk we are able to select the most suitable and clearest portion of the cornea outside of the center, near or in the visual area, which is best for visual purposes. If this favorable spot is too far from the visual area, and not in front of the pupil, an iridectomy may be performed behind it, and thus an artificial pupil be made. Not only are we able to select this spot with the ophthalmometer, but, by its aid, we can measure the astigmatism here, — only approximately cor-

rect, of course, — and we are able often to improve the vision with cylinders in many of the cases.

I am perfectly aware of the fact that the astigmatism is of such a high degree in many of these cases of conical cornea, as it is also many times after cataract extraction, that the ophthalmometer, as now constructed, is only capable of giving the relative difference of the dioptric power of the two chief meridians of the cornea, and not the absolute or exact measurements in such cases. Helmholtz,[1] long ago, pointed out the fact that, in order to measure the curvature of the cornea in its various meridians, one can only use images which are considerably smaller than the radius of curvature of the cornea, — not larger than one-quarter of the size of the latter. He also shows that one should endeavor to accurately determine these images to the one-hundredth part of a millimeter if one wishes to calculate accurately the radius of the cornea to the one two-hundredth part of its size.

Reid,[2] in an article on the "Scope and Limits of Ophthalmometry," says, "With Javal's instrument, with an image of 3 mm., and with the portable ophthalmometer (Reid's), with an image of 2 mm., it is clear that from the spherical aberration the absolute size of the radius cannot be determined without reduction, as Leroy has done." And Reid also suggests that in very high degrees of astigmatism it would be better to have an image of only 1.50 mm. in diameter, especially when it comes to measuring the strongest curved meridian.

In order to have such an image it would be necessary to have an extra prism for the instrument, which would cause a doubling of only 1.50 mm., that is, giving an image of 1.50 mm. in diameter. Such a prism can be obtained from the manufacturers.

For all ordinary cases, however, the instruments, as now

[1] Graefe's *Arch. Oph.* Vol. I, No. 2, p. 854.
[2] *Annals of Ophthal.*, St. Louis, Vol. VI, p. 456.

constructed, are accurate enough. In the exceptional cases of very high degrees of astigmatism, as in conical cornea and some cases after cataract extraction, the difference in the curvature of the two chief meridians, as a rule, can be approximated closely, as can also the position of these two chief meridians.

The following case of conical cornea will serve to illustrate the points referred to. See, also, the chapter on Astigmatism after Cataract Extraction.

CASE XCIV. *Conical cornea, extreme in the right eye and marked in the left; Irregular astigmatism; No improvement with glasses in the right, but the vision was brought from $\frac{6}{200}$ to $\frac{20}{50}$ with glasses in the left eye.* — December 7, 1898, Miss Nellie F., aged thirty-three years, general health is poor, being subject to sick headaches, especially severe at the menstrual periods. She had good sight until thirteen years of age, when she began to menstruate very profusely, losing great quantities of blood at each period, and the sight began to fail rapidly, particularly in the right eye. She became very anaemic, and the vision continued to grow worse for two years, after which time it appeared to remain about as it is now. She had considerable pain in the eyes for the first two years. She consulted an oculist at that time, and also another when twenty-three years of age. Besides tonics, they prescribed a simple minus 5 D. spherical glass, which gave her $\frac{20}{200}$ vision in the left eye, but no improvement in the right.

Ophthalmometer. — Astigmatism against the rule, about 4 D., axis 165° − or 75° +, with irregular astigmation right eye; astigmatism against the rule, 8 D., axis 30° + or 120° − left eye, with irregular astigmatism.

Test cards and trial lenses. —

R. V. $\frac{1}{200}$: not improved.

L. V. $\frac{6}{200}$: $\frac{20}{50}$ W. − 10 D. cyl., 120°.

Reads Jaeger No. 1 from 4 to 10 inches with the left eye.

Ophthalmoscope. — Shows an extreme degree of conical cornea right, and a marked degree left eye. The shadow crescent of conical cornea is beautifully shown in each. In the right eye the shadow was so pronounced as to suggest an opacity in the lens, but oblique illumination showed a perfectly clear lens, as well as a clear cornea. The ophthalmoscope also showed the lens to be perfectly clear when the pupil was dilated to permit of a thorough examination. The parallactic movement was very marked and nicely shown in the left fundus. The fundus in the right eye could be seen but indistinctly with either the direct or indirect method: the fundus in the left could be seen very well, but only parts of it at a time, the blood vessels and background changing with each movement of the eye or of the ophthalmoscope. There were no opacities in the vitreous, and the fundus appeared normal.

Retinoscopy was totally useless in this case, and even the ophthalmoscope was of but small service in the estimation of the refraction. The subjective test with the clock-dial was altogether unsatisfactory. The ophthalmometer and the subjective tests with the test case and trial lenses were the only methods of value in giving the glasses.

After several tests without a mydriatic and two or three with a mydriatic, in which all of the tests substantially agreed, I ordered for the right -5 D. sphere (simply to balance the glass in the left eye), and for the left -10 D. cyl., 120°, in the form of a periscopic sphero-cylindric lens. Instead of giving a -10 D. cyl., 120°, I ordered -5 D. -10 D. cyl., 120° $+5$ D. That is, a $+5$ sphere was ground on one side of the glass, and -5 D. sphere and -10 D. cyl., 120° were ground on the other side. In effect, this glass is the same as the -10 D. cyl., 120°.

These glasses were for the distance. For reading, I prescribed in the right – 5 D. as for the distance ; and in the left eye + 3.50 D. cyl., 30° – 6.50 D. cyl., 120°, which magnified the print more than the distance glasses. With these she could read Jaeger No. 1 from four to eight inches better than with the distance glasses. But she could read the Jaeger No. 1 with her distance glasses, and with the advantage of holding the print a little farther from the eyes, though it was some smaller. I advised her to use the distance glasses as much as possible.

For a description of periscopic and toric lenses, see the chapter on cataract glasses, where instead of giving a simple bi-convex lens or sphero-cylinder, a toric lens is often given with great advantage.

In the present case, the first few days after the patient had her glasses they made her very dizzy, and she could not wear them in the street, but after a few days' trial, she was able to go on the street at will ; not only this, but she was able to wear the one pair of glasses, the distance, both for the street and reading. Her headaches were made worse and the attacks more frequent for the first few weeks after putting on the glasses ; but her vision was so greatly improved that she persisted in the use of the glasses, and now, four months after, the headaches are much less frequent and less severe. In fact, I saw her within the week (April 7, 1899), and she tells me she has not had a single headache for the last month. Her general health also has improved.

I not only measured this patient's cornea near the center (where the visual lines cut), but 15° above, below, in, and out. I also located the extreme tip of the cone in each eye, which was down and out, between 7° and 8° from the center of the cornea in each.

The disk of Placido was of value in this case, and I give drawings of its reflections from the cornea in each eye. The marked flattening of the circles into irregular ovals is well

shown, the ovals being more drawn out on the side away from the center of the cornea (see Figs. 91 and 92).

The ophthalmometric readings in this case, as indicating the radius of curvature and the refractive power of the cornea in its two chief meridians at various points on its surface, were extremely interesting to me, and I give them below.

FIG. 91 (left eye).

Right eye: the radius of curvature at the center (where the visual line intersects) in the meridian at 75° was 4.38 mm., with a refractive power of 76 D. The meridian at 165° had a radius of only 4.16 mm., with a refractive power of 80 D.

Of course these results are only approximative, because the spherical aberration was marked and the irregular astigmatism so considerable that the images of the mires were made indistinct and irregular in outline; not so indistinct, however, that approximate measurements could not be made.[1] For, while the irregular astigmatism was very considerable, it was not near so marked as after many cases of cataract extraction, or as in some cases where corneal opacities are present.

[1] It should be noted in this connection that a cornea with such a small radius of curvature cannot be measured with the ophthalmometer with the single movable mire, but only with the ophthalmometer with double movable mires. This is because with the single movable mire the object cannot be made large enough. For a description of the improvement of double movable mires, see Appendix.

The radius of curvature of the cornea changed greatly in the same meridian; for instance, 15° below the center, in the meridian at 75°, the radius was 5.38 mm., that is, one whole millimeter longer than at the center, and with a refractive power of only 62 D. as against 76 D. at the center. The radius in the meridian at 165° was 4.76 mm., with a refractive power of 70 D.

By these measurements it will be seen that while the radius of curvature has increased in length in each meridian, relatively it increased more rapidly in the meridian at 75° than it did in the one at 165°, and, therefore, the astigmatism is much more marked 15° below the center of the cornea than at its center, in fact, just twice as great, being 8 D.

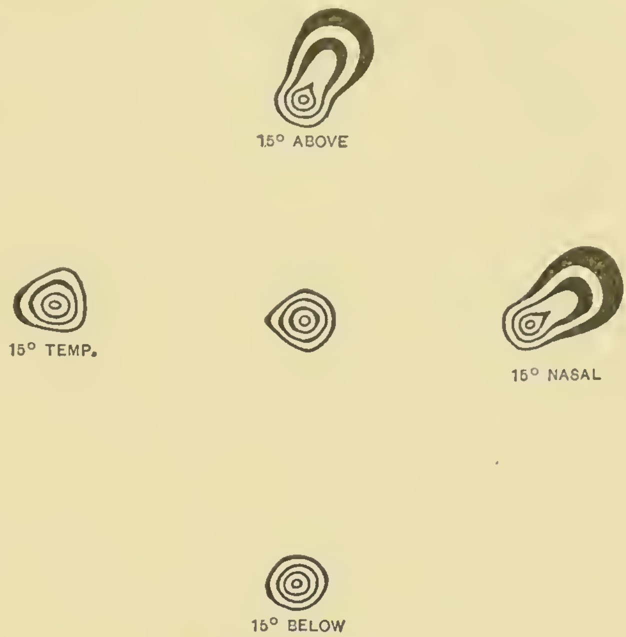


FIG. 92 (right eye).

Left eye: the left eye could be measured with greater precision than the right, because the cone was not nearly so marked as in the right.

The radius of curvature at the center, in the meridian at 120°, was 6.20 mm., with a refractive power of 50 D., while the radius in the meridian at 30° was 5.96 mm., with a refractive power of 56 D. The mires of the ophthalmometer when turned from the second position, after being approximated, back to the primary position, overlapped eight steps, indicating an astigmatism of 8 D. against the rule. I may say that, in the right eye, a similar discrepancy in the difference in refractive power of the two chief meridians, as calculated from the radius

of curvature of these meridians, and as indicated by the overlapping of the mires when turned from the second position back to the primary position, existed. But when the radius of curvature in one and the same medium changes so rapidly, as in conical cornea, such discrepancy may be expected.

15° below the center (left), the ophthalmometer showed astigmatism against the rule, 5 D., 165° + or 75° –. The radius of curvature in meridian at 75° was 6.18 mm., with a refractive power of 54 D., while the meridian at 165° had a radius of 5.75 mm., with a refractive power of 58 D.

15° to the temporal side of the center of the cornea, the ophthalmometer showed astigmatism against the rule, 6 D., axis 150° + or 60° –. The radius of curvature in the meridian at 60° was 6.96 mm., with a refractive power of 48 D., while the meridian at 150° had a radius of 6.18 mm., with a refractive power of 54 D.

15° above the center, the ophthalmometer showed astigmatism against the rule, 11 D., axis 15° + or 105° –. The radius of curvature in the meridian at 105° was 9.33 mm., with a refractive power of only 36 D., while the radius at 15° was 7.11 mm., with a refractive power of 47 D.

15° to the nasal side of the center, the ophthalmometer showed astigmatism with the rule, 13 D., axis 75° + or 165° –. The radius at 75° was 7.11 mm., with a refractive power of 47 D., while the meridian at 165° had a radius of 9.88 mm., with a refractive power of 34 D.

Although both of the chief meridians of the left eye at the center (the point cut by the visual line) had a radius of curvature much shorter than the average (7.82 mm.), from which we would expect some myopia in addition to the astigmatism, nevertheless the patient would not accept any minus sphere, neither would she accept any plus glass, cylinder or sphere, either with or without the mydriatic.

I tried the hyperbolic glasses of Raehlmann in this case,

but could find none which improved the vision more than the ordinary glasses.

For the benefit of those who have not had experience with the hyperbolic glasses of Raehlmann, I may say that they come in two series, designated "A" and "B" respectively, and in each series there are eleven glasses. In the series designated "A" the axis of the hyperbola is one-third of a millimeter, while in the series designated "B" the axis of the hyperbola is two millimeters. In order to fit such glasses, the best plan is to hand the patient each glass in turn in both series and let her move it in different positions in front of the eye until the part of a glass is found which gives the best vision, and this is marked on the glass and sent to the optician to be cut and centered to suit the spectacle frames. I have noticed that the vision is often much improved by holding the glass obliquely in front of the eye, just as after some cases of cataract extraction where there is a large amount of astigmatism. These hyperbolic glasses may be obtained through any good optician.[1]

The hyperbolic glasses, besides being costly, are objectionable in another way: they narrow the field of vision, that is, the patient in order to see through them has to look directly through the optic axis; for that reason they are not as suitable for the street as for near work.

In some cases of conical cornea the vision is improved by means of the stenopaic slit and spherical glasses, but in this case it was not. While on this topic of conical cornea, it may be stated also that there is such a thing as a contact glass. That is, the glasses are ground in the shape of a meniscus, so that the posterior surface fits the front of the eyeball, somewhat after the nature of the artificial eye, while the front surface is ground so as to correct the refractive error. The glasses, I believe, are made in Switzerland. I have known of but one

[1] Mr. Meyrowitz, of this city, keeps them in stock.

case in which they were tried, and in this case they had to be given up because of the irritation to the eye. They are worn, of course, just as an artificial eye would be.

S. M. Burnett, of Washington, was the first observer in this country to make use of the ophthalmometer in measuring conical cornea; for the report of his very interesting case, see *Archives Ophthal.*, Vol. XIV, 1885, p. 169.

CHAPTER IX

STRABISMUS — INSUFFICIENCIES OF THE RECTI MUSCLES — AMBLYOPIA — ILLUSTRATIVE CASES

THE symptom, strabismus, convergent and divergent, is so intimately connected with and dependent upon errors of refraction, that a brief history of the discovery of this relation by Donders, and its bearing upon this subject in general, is not out of place here. In fact, a knowledge of this relation, together with a knowledge of the intimate relation between convergence and accommodation, is of first importance, if a correct understanding of this subject is to be had.

Not until 1864, when Donders gave his epoch-making book — *Accommodation and Refraction of the Eye* — to the world, was the condition, or rather symptom, squinting, explained in a satisfactory way, and the whole subject placed on a scientific basis. All observers before Donders left this subject in a hazy condition, even so great a man as Von Graefe failing to recognize the true cause of strabismus in most cases, to wit, errors of refraction. Von Graefe attributed the symptom of squinting chiefly to defective balance, or want of equilibrium of the external muscles of the eyes. He thought that accommodation had something to do with it, but he never recognized the true connection, as *cause* and *effect*, between hypermetropia and convergent strabismus, and myopia and divergent strabismus. And while, as Donders says, many useful hints had been given in literature as to the cause of strabismus, yet no one had sought the cause of strabismus (convergent) in hypermetropia. And he further adds: "Indeed, this could scarcely be otherwise. It is only a few years [1864 is the date of Donders' book]

since hypermetropia was properly understood; and the forms which are wholly or in great part latent were overlooked until I satisfied myself of their existence, and immediately began to perceive their relation to strabismus."[1] Again, in reference to divergent strabismus, he says: "On the whole, little satisfaction is obtained by consulting the more recent copious literature on strabismus, with reference to its causes. Strabismus divergens, in particular, is very imperfectly treated of. A distinction of the causes, according to the different forms, is not to be met with, and where the causes of strabismus in general are spoken of, the writers have evidently been filled with the idea of strabismus convergens."[2]

Donders also quotes Von Graefe to the effect that this observer believed that insufficiency of the internal recti muscles was the cause of divergent strabismus.

It was Donders' thorough investigation of hypermetropia, myopia, and errors of refraction in general that revealed to him the close relation between accommodation and convergence, and gave to him the true relation of cause and effect that existed between hypermetropia and convergent strabismus, and myopia and divergent strabismus.

The method or way in which hypermetropia produces convergent strabismus is explained as follows: In order that a patient with hypermetropia may see well for the distance, he must use a considerable amount of accommodative effort, and for near points even more, for, in such cases, the eyeball being too short, the rays focus behind the retina, and accommodative effort must be made to bring them up to it, if a clear image is to be obtained. As is now well known, accommodation and convergence are closely associated, and what calls one into play, at the same time and within certain limits, calls the other, hence, when the patient has to use an excessive amount

[1] Donders, *Accommodation and Refraction of the Eye*, p. 306.

[2] *Loc. cit.*, p. 415.

of accommodative effort, he at the same time calls into action the convergence. In doing this, however, sometimes the internal recti overact, and one eye, usually the weaker one, shoots inward too far; squints, if you please, leaving the better eye directed on the object. By suppressing the image in the weaker eye and squinting it inward too far, an excessive convergence is obtained, which, in turn, reacts on the accommodation in the good or fixing eye, and assists it by increasing its action in maintaining a clear image in that eye. Thus single binocular vision for the two eyes is sacrificed in order that the patient can see clearly with one eye.

Myopia produces divergent strabismus in the following manner: In looking at distant objects, or even at near objects, if the myopia is of moderate or large amount, myopes use no accommodative effort at all; for the eye, being too long, is always too strongly refractive (the rays focussing in front of the retina), and, if accommodative effort is brought into use, it only makes matters worse. As a consequence, they relax their accommodation to the utmost, and, as convergence is controlled by the same nerve, — the third, — and acts in unison with accommodation within certain limits, the convergence in such cases is relaxed at the same time. By this continued relaxation of the convergence, one eye — as a rule, the weaker-sighted one — turns too far out, that is, squints outward or diverges, while the better eye fixes the object.

While Donders maintained that hypermetropia was the cause of most cases of convergent strabismus, and myopia the cause of most cases of divergent strabismus, yet he did not lose sight of the contributory and auxiliary causes which coöperated in the production of strabismus.

In *Hypermetropia*, the causes are of a twofold nature: "(1) those which diminish the value of binocular vision; (2) those which render the convergence easier."[1] Under the

[1] *Loc. cit.*

first class of causes he includes: (1) difference in acuteness of vision of the two eyes, due to congenital defect in the retina, or to more marked refractive error in one eye than the other; (2) spots on the cornea, or anything that interferes with the acuteness of vision. In the second class of causes he includes: (1) faulty structure or innervation of the external muscles of the eye; (2) a large angle *alpha*, especially when associated with a limited range of accommodation.

To "paresis of accommodation" alone causing convergent strabismus, he gives but little weight, saying, "Diminished energy, or paresis of accommodation, by itself, is as little liable to produce strabismus as is the range of accommodation connected with the increase of years." On the other hand, Javal gives weight to this point, and thinks a "temporary paresis of accommodation" is a frequent cause of strabismus convergens, and explains it thus, "A patient whose accommodation suddenly fails is obliged to make a great accommodative effort, which is facilitated by an excessive effort of convergence, that is to say, by an attack of strabismus."[1]

In *Myopia*, two sets of influences tend to produce divergent strabismus, which Donders gave under the following headings: "(1) circumstances which promote movements outwards; (2) such as deprive binocular vision of its value."

Under the first set of influences he gives: (1) too strong external recti muscles; (2) small or even negative angle *alpha*, due to outward displacement of the visual lines; (3) long and superficially placed eyeballs.

Among the second class of causes he mentions: (1) unequal refraction of the two eyes; (2) diminished vision in one eye.

To the first set of causes should be added faulty innervation or under-developed internal recti muscles.

Buffon, Müller, Reute, and others preceded Donders in connecting myopia and divergent strabismus; but none of them

[1] Cited by Roosa, *The Post-Graduate*, December, 1897.

had given the full significance of the relation between convergence and accommodation in these cases.

I have given Donders' views on strabismus somewhat at length, because, as I believe, they embrace the correct explanation of the method of production of the symptom, strabismus, and the true causes therefor. I may add, but little has been added to the knowledge of the subject, that is, as to its causes, other than of an auxiliary nature, since then. As to its treatment, operative and otherwise, much has been done.

Roosa, in his recent *Treatise on Diseases of the Eye*, gives the following conclusions in regard to the etiology of strabismus convergens, which, as will be seen, agree in the main with the conclusions of Donders. However, he lays more stress on a higher degree of hypermetropia or hypermetropic astigmatism in one eye than the other than did Donders; "sufficient," as he says, "to produce what may be fairly termed an organic amblyopia," as an etiological factor in the production of squint. His conclusions are as follows: —

"I. Convergent strabismus is generally associated with hypermetropic astigmatism or hypermetropia.

"II. It is probably caused by congenital anisometropia (unequal refraction) in the majority of cases; that is to say, by the inability to secure binocular single vision.

"III. In a small contingent it is associated with equal vision in each eye. In such cases the patient fixes with either eye alternately. Why the strabismus then occurs is to me uncertain. If it were merely from hypermetropia, why do not nearly all people who are not myopic squint?

"IV. Opacities of the cornea, or occlusion of the pupil of one eye, very much favor the occurrence of squint in eyes of any refraction.

"V. If strabismus convergens be caused chiefly by anisometropia and refractive anomaly, it is not congenital, but it occurs at the age of from two to five years.

"VI. If congenital squint or organic disease of the retina exists, suspicion should be excited that it is caused by central disease."

In regard to the query, in Conclusion III, as to the cause of the squint in hypermetropic eyes of equal acuteness of vision, I may say I believe it to be caused chiefly by a very large angle *alpha*, which is usually to be found in such cases. I may say also that I believe a very small or zero angle *alpha* accounts in a great measure for those anomalous cases of divergent strabismus sometimes present in hypermetropia; and that a very large positive angle *alpha* may account for the likewise anomalous condition of convergent strabismus at times present in myopia. As the angle *alpha*, as an accessory cause of strabismus, will be discussed a little farther on, this bare statement is sufficient here.

The most recent investigations of the anomalies of motility of the eye, in this country, are those by Duane, in a prize essay entitled: "A New Classification of the Motor Anomalies of the Eye, based upon Physiological Principles."[1]

In this essay he has made a very careful study of the motility of the eye, has measured the strength of the ocular muscles, tested their individual and associated movements, and as a result of his investigations has prepared a new classification of the motor anomalies of the eye, as he says, "based on physiological principles." I have not adopted the classification, but would refer my readers to the paper itself, which, I believe, is now to be had in book form.

The conclusions that I have given above, as to the etiology of strabismus, I believe to be a fair expression of the mind of the profession of to-day. However, there were, and still are, some who believe that strabismus is due largely to the defects in the muscles themselves, while others believe it to be of central origin, or the result of imperfect innervation of the differ-

[1] *Annals of Oph. and Otol.*, October, 1896, January, 1897, and April, 1897.

ent muscles of the eye. But Donders' explanation, that in the fixed conditions of the eyeball was to be found the cause of most cases of strabismus, and that among the fixed conditions hypermetropia and myopia were the most potent factors, has never been overthrown. In fact, almost all observers since his first published views on this subject have concurred in his belief as to the great influence of hypermetropia and hypermetropic astigmatism, and myopia and myopic astigmatism in the production of strabismus, convergent and divergent respectively. It has been shown by many observers and numerous tables of statistics that hypermetropia or hypermetropic astigmatism is present in from 75 to 85 per cent of all cases of convergent strabismus (some observers giving as high as 98 per cent), while myopia or myopic astigmatism is present in from 60 to 75 per cent of all cases of divergent strabismus.

But it is concerning the *accessory* causes of strabismus that most dispute and discussion have arisen. Some authorities lay great stress on a "preëxisting disturbance of muscular equilibrium." That is, to insufficiencies which finally terminate in actual strabismus. Other authorities have placed much emphasis on the amblyopia (congenital, or acquired from whatever cause), usually present in the squinting eye, as the chief accessory cause in the production of the squint. For my own part, I believe that amblyopia plays a more important part as a predisposing cause of squint than do insufficiencies of the ocular muscles.

Of course, all observers agree as to the influence of the long and superficially placed eyeball in myopia in the production of divergent strabismus. Here the axis of the eyeball, being too long, naturally assumes the direction of the axis of the orbit, which, as is well known, is directed forward and outward.

As to the "paresis of accommodation" causing strabismus convergens, some authorities give it little weight, while others lay stress on the point. So far as my own observa-

tions go, I must say I have not observed a tendency to convergent squint in such cases. I believe its absence in such cases is to be explained on the same ground upon which Donders explained the absence of convergent strabismus, as a rule, in very high degrees of hypermetropia. He says: "In such cases the power of accommodation is, even under abnormally increased convergence, not sufficient to produce accurate images, and such hypermetropics are thus led rather to the practice of forming correct ideas from imperfect retinal images than of, by a maximum of tension, improving the retinal images as much as possible."[1] I have had under my care for the last four months a young girl, aged thirteen years, with paresis of accommodation from no apparent cause, unless an attack of diphtheria four years previously, which affected the voice for a short time after, but not the vision, can be given as a cause. This patient has no tendency whatever to squint. She has a hypermetropia 2 D., vision $\frac{20}{20}$, which is brought up to $\frac{20}{15}$ with + .75 D. sphere, but she cannot read Jaeger No. 1 closer than eight inches with her distance glasses on. Her mother brought her for examination because she held the print too far from her when reading, "as far as an old person," she said. The patient had no asthenopia whatever, was in perfect health, and had always been, except for the attack of diphtheria already spoken of.

In several other cases of temporary paresis of accommodation which have come under my observation, I have not noticed any tendency to convergent strabismus. But, as I said above, these few cases I have seen are not enough to justify me in drawing positive conclusions therefrom.

The Angle Alpha

The angle *alpha* as an accessory cause of strabismus is of more importance than has, as a rule, been accorded it. The

[1] *Loc. cit.*, p. 301.

angle *alpha*, that is, the angle between the visual line (*FO*, Fig. 93) and the long axis of the cornea (*CD*, Fig. 93) in the horizontal plane, has considerable influence in the production of strabismus, according to Donders' and Hamer's investigations. As I wish to convey a clear idea, to the beginner especially, of the influence of the angle *alpha* as an etiological factor in the production of strabismus, I shall give some diagrams to help make clear the text on the subject.

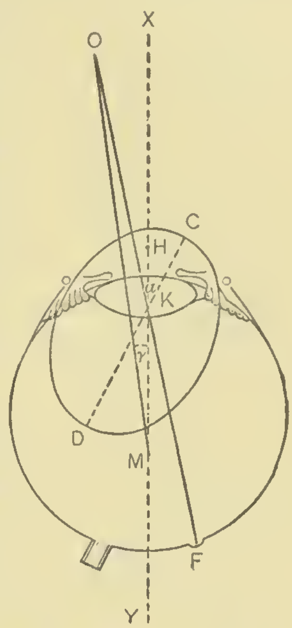


FIG. 93.—Angle *alpha* (after Roosa). *XY*, optic axis; *H*, principal points combined; *K*, nodal points combined; *M*, center of motion; *FO*, line of vision; *MO*, line of fixation; *CD*, greater axis of corneal ellipsoid; *OKC*, angle *alpha* (α); *OMX*, angle *gamma* (γ).

The figure produced to show the angle *alpha* is very diagrammatic. It represents the right eye as seen from above. *XY*, the optic axis, is the line joining the center of the cornea and the posterior pole of the eye. *CD* is the longest axis of the corneal ellipsoid. In the figure, the apex (*C*) of the corneal ellipsoid is represented as being far to the temporal side of the center of the cornea, the spot on the cornea cut by the optic axis, *XY*. As a matter of fact, these points almost coincide, and are so treated in actual practice.

This being so, the long axis (*CD*) of the corneal ellipsoid and the optic axis (*XY*) would coincide, and they, also, are considered as one and the same in actual practice.[1]

The angle *alpha*, *OKC*, is called *positive*, or plus, when the

[1] And, when they are so considered, the angle *gamma*, formed between the line of fixation, *OM*, and the optic axis, *XY*, varies, that is, increases and diminishes, in exact proportion with the angle *alpha*. Moreover, they become nearer equal the farther the object of fixation is removed from the eyes, and, when the object is at twenty feet or more, they become equal.

front portion of the long axis of the corneal ellipsoid falls to the outer or temporal side of the visual line (Fig. 94); and this is the case in most eyes.

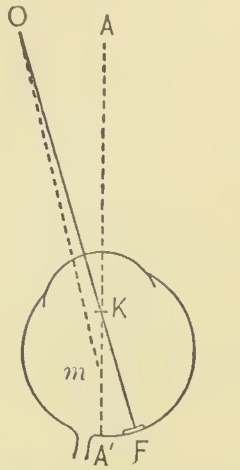


FIG. 94. — Positive angle *alpha* of twelve degrees, right eye.

It is said to be *negative*, or minus, when the front portion of the long axis of the corneal ellipsoid falls to the inner or nasal side of the visual line (Fig. 95). This is comparatively rare, but sometimes occurs in myopia. When the visual line and the long axis of the corneal ellipsoid coincide, it is evident that there can be no angle *alpha* at all; then it is said to be nil.

Now, in the first place, let us see what determines the character and the size of the angle *alpha;* and, in the second place, how the angle *alpha* influences the eye to squint.

A. The *character* of the angle *alpha* is determined by: —

1. The position of *the yellow spot*, or *macula lutea*, in reference to the posterior portion of the optic axis of the eye, that is, the posterior pole of the eye. It should be remembered that the optic axis and long axis of the corneal ellipsoid are regarded as *one* in practice, as represented in the two last figures. As long as the macula is situated to the outer or temporal side of the posterior pole of the eye, the angle *alpha* must be positive; for the visual line, FO (Fig. 93), must necessarily cut the cornea to the inner or nasal side of the optic axis, XY. Furthermore, the further the macula is situated toward the temporal side of the posterior pole of the eye, the larger will the positive angle *alpha* be. If the macula lutea and the posterior pole of the eye are at the same spot, then the visual line and optic axis must

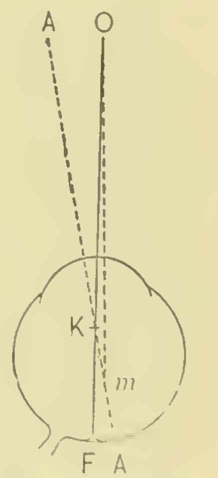
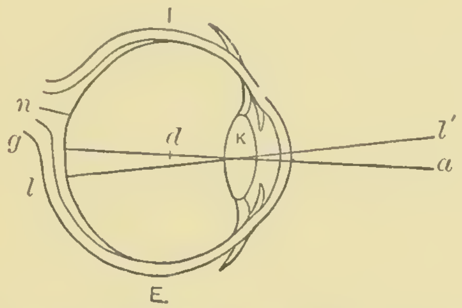
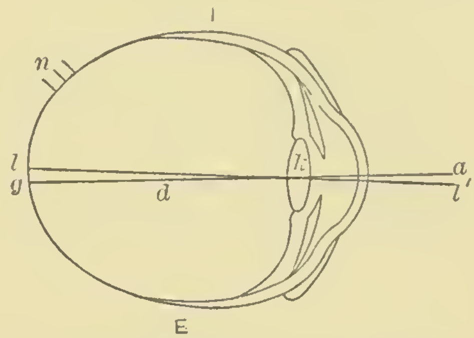


FIG. 95. — Negative angle *alpha* of six degrees, right eye.

coincide; and there is no angle *alpha*, or it is nil. If the macula lies to the inner or nasal side of the posterior pole, the visual line, *FO* (Fig. 95), must cut the cornea to the outer or temporal side of the optic axis, and the angle *alpha* becomes





FIGS. 96, 97, AND 98. — Fig. 96, emmetropic eye; Fig. 97, myopic eye; Fig. 98, hypermetropic eye. *I*, nasal side; *E*, temporal side; *n*, optic nerve; *ga*, optic axis; *ll′*, visual line; *d*, center of motion; *K*, nodal point. (After Donders.)

negative; and the farther inward from the posterior pole of the eye the macula is situated, the larger the negative angle *alpha* will be.

2. The length of the eyeball itself influences the size of the angle *alpha*.

In emmetropia, the angle *alpha* is positive, and averages 5°; in hypermetropia, it is positive, and averages 7.3° in non-squinting eyes; while, in myopia, it is, as a rule, positive, but may be nil or negative, and averages a little less than 2°. These are the figures given by Donders; and this author explains the influence of the length of the eyeball on the size of the angle *alpha*, as follows: —

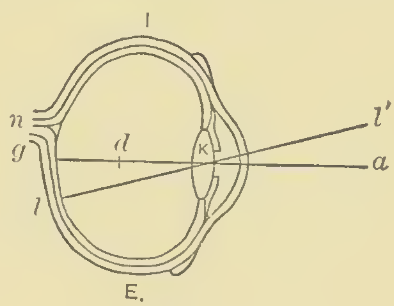


FIG. 98.

"The distance, *kg* (Fig. 98), from the nodal point to the retina is to be taken into account. It is evident that, if in the hypermetropic eye, where this distance is particularly short, the yellow spot *l* is only at the ordinary distance from *g* (a

point of the prolonged axis of the cornea), the angle *alpha*, under which ll' and ga intersect one another in k, becomes greater. In this, therefore, really lies in part the cause of the greater value of *alpha* in hypermetropic eyes; but, for the most part, this greater value must still be explained by the more external position of the yellow spot.

"This position is connected with the arrested development, especially of the external portion of the hypermetropic eye."[1] A glance at Fig. 97 shows the influence of myopia to diminish the size of the angle *alpha*, by reason of its longer optic axis.

B. *How does the angle alpha influence the eye to squint?*

It is apparent, if the angle *alpha* is large, as it often is in high degrees of hypermetropia, that the long axes of the corneæ (and the summits of the corneæ) will be directed in a divergent direction when the visual lines are parallel (Fig. 99).

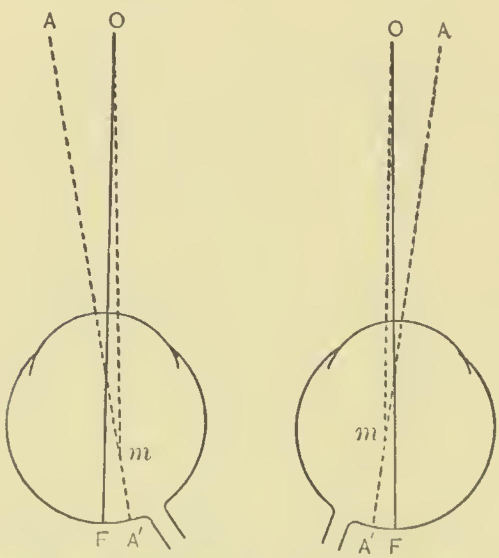


FIG. 99. — Showing an apparent divergent squint in hypermetropia of high degree, with a large angle *alpha* (positive).

If this angle amounts to as much as 6° in a normal eye with a corneal radius of curvature of eight millimeters (a little above the average), the linear distance on the cornea, from the visual line to the optic axis (summit of the cornea), would be .9 millimeter, or, practically, one millimeter. With an angle *alpha* of 12°, as is sometimes found in hypermetropia of high degree, this distance would be nearly two whole millimeters. Therefore, with the visual lines of such eyes directed straight ahead and parallel, the summit of each cornea would diverge two millimeters, and the patient would appear to squint outward,

[1] *Loc. cit.*, p. 249.

although single binoeular vision was present. This apparent divergent squint is the so-ealled *strabismus incongruus* of Müller, or the *apparent* squint of later writers. This apparent squint appears to be divergent in hypermetropia, and eonvergent in myopia. I have seen, more than onee, after tenotomy for eonvergent squint in hypermctropia, apparent divergent strabismus oceur; and, before the sereen test was tried, an overeffect from the operation was thought to be present. However, with the sereen test, both eyes remained fixed when eovered and uncovered, showing the visual lines to be parallel and fixed on the objeet. Again, I have seen eases, and have eongratulated myself, in faet, on the beautiful result obtained after tenotomy for eonvergent squint, where the eyes were apparently straight and directed to the same objeet; but, on the sereen test being applied, first one eye and then the other turned outward, showing conclusively that the visual lines still eonverged and that the patient did not use the eyes together.

Ineidentally, I may say here, that this sereen test is a simple and easy way to deeide between a true and a false or apparent strabismus. It eonsists simply in covering first one eye and then the other with a eard, having the patient look at a distant light, preferably a candle, with the uncovered eye. If the eye that is covered ehanges position when uncovered (the eard being plaeed in front of the other eye), it is a true squint, and shows that the visual lines of the two eyes are not direeted to the same point. If the eye turns outward on being uncovered, it shows a *convergent* squint to be present, because while behind the eard or sereen it turned inward, while the uncovered eye fixed the object. On the other hand, if the eye turns inward on being uneovered, it shows a *divergent* squint to be present, because, while the other eye fixed the objcet, its visual line diverged, and only turned inward when uncovered and the opposite eye was eovered. The same test may be made by

having the patient look at a near object, as the finger, or a pencil.

The large angle *alpha*, sometimes present in high degrees of hypermetropia, and giving rise to an apparent divergent strabismus, may lead to a true convergent strabismus, in the following manner: —

Such eyes, in order to see binocularly and singly for the distance, have to direct their visual lines parallelly. But in doing this they have actually to diverge the centers of the corneæ; to do which the external recti may not be quite strong enough, especially since these patients have to exercise accommodation to see well even for the distance. This act of accommodation in itself stimulates convergence to a certain extent, which latter force would actually oppose the outward movement of the eye. If, therefore, these eyes have to make an effort, on account of a wide angle *alpha*, to keep straight, that is, their visual lines parallel and directed to the same object in the distance, when they come to view near objects the tendency of the visual lines to unduly converge will be greater still, and the relative insufficiency of the external recti muscles for the distance may be converted into a true convergent strabismus for the near point. Donders and Hamer were the first to investigate this point, and to bring statistics to bear showing the influence of a large positive angle *alpha* in producing convergent strabismus. These observers measured the angle *alpha* in a number of cases of hypermetropia with convergent strabismus, and the same angle in a number of cases of hypermetropia of about the same degree as those which squinted, and found that the angle *alpha* averaged in size a little more than one degree larger in the squinting cases than in the non-squinting ones.

Donders says: "The result therefore is, that, with equal degrees of hypermetropia, high values of *alpha* especially predispose to strabismus convergens. To this I attach more im-

portance, because it *in general* proves, that the greater angle *alpha*, proper to hypermetropia, is not indifferent in its bearing on the connection between hypermetropia and strabismus." [1]

My own experience has led me to the same conclusion as that formed by Donders, in regard to the influence of a large angle *alpha* as an accessory cause in producing convergent strabismus; not only that, but I believe many of the anomalous cases of divergent squint in hypermetropia are to be explained by a very small positive angle *alpha*, or even with the angle nil, rather than by any muscle defect, either of insertion or structure, or imperfect innervation. My own observations on this point, and the cases reported farther on in this chapter, have led me to this conclusion.

On the same ground of reasoning, the anomalous cases of convergent strabismus in myopia are to be accounted for most of the time, I believe, by the presence of a large positive angle *alpha*.

A large negative angle *alpha* has the same tendency to produce a divergent strabismus in high degrees of myopia that the positive angle *alpha* has in causing convergent strabismus in hypermetropia, except that it works in a reverse order.

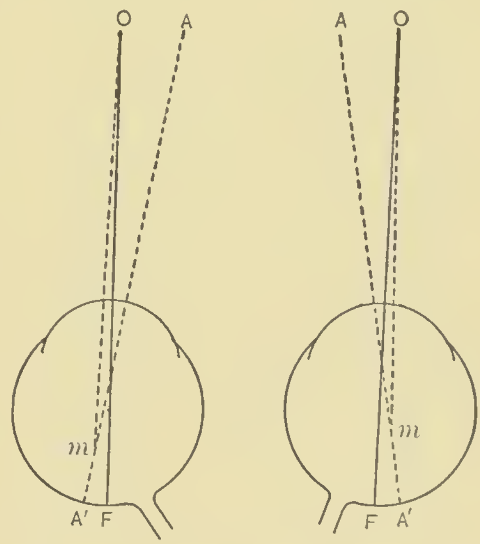


FIG. 100. — Showing the influence of a large negative angle *alpha* in producing an apparent convergent squint.

In such cases, in order to secure single binocular vision and to have the visual lines directed parallelly, the centers or summits of the corneæ must be directed inward. Now in high degrees of myopia it is hard to turn the front of the eye inward on account of the long eyeball incident to such cases; for the

[1] *Loc cit.*, p. 301.

optic axes of these eyes have a tendency to coincide with the axes of the orbits, which latter have an *outward* direction. If it is difficult, therefore, for these eyes to turn the centers of the corneæ relatively too far inward in order to have their visual lines parallel for distant objects, is it not much more difficult for them, with a wide angle *alpha*, to turn the eyes still farther inward in order to fix near objects with both eyes at the same time? In fact, the wider the negative angle *alpha*, the more difficult it is for the eyes to fix with both eyes at once, hence the direct influence it exerts in producing a true divergent squint, though it gives the semblance to the eyes of convergent strabismus at times.

Such is the influence of the angle *alpha*, positive and negative, in causing the eyes to squint. I have considered it somewhat at length, in order that the beginner might understand it, both as to the influence refractive errors have in the production of the angle *alpha* itself, making it positive or negative, and smaller or greater, as the case may be; and the secondary influence the angle has in causing a true squint. Furthermore, it will teach him to observe between true and apparent or false squint.

But it is not merely to show the influence of the angle *alpha* in the production of squint that I have gone rather fully into its exposition here, but also to show how the angle *alpha* may influence the reading of the ophthalmometer and the fitting of glasses. In an article in the *New York Medical Journal*,[1] February, 1895, I have explained this influence.

Those who are only fairly well acquainted with the use of the ophthalmometer are aware of the fact that the whole of the cornea is not measured in an ordinary examination, but only a very small portion of it — a space of only $2\frac{1}{2}$ to 3 millimeters in diameter. Furthermore, the center of this space does not coincide with the center of the cornea, except when the visual

[1] See also Appendix of this book.

line coincides with the long axis of the cornea,[1] but with that point on the cornea intersected by the visual line, which point is usually a little to the nasal side of the center of the cornea (2° to 5°), and, as a rule, on a horizontal line with it. However, on rare occasions this point is on the temporal side of the center of the cornea, that is, when there is a negative angle *alpha*.

When this angle is large, especially when there is a high degree of astigmatism, and associated with a large amount of hypermetropia or myopia, the readings of the ophthalmometer do not correspond so closely with the subjective tests as in the cases with lower amounts of astigmatism and with a small or average angle *alpha*. For example, in an eye with a radius of curvature of 8 mm., an angle *alpha* of 6° is 0.9 mm., or practically 1 mm., and with angle *alpha* of 12° it would, of course, be 2 mm. (see Fig. 94). In such case, therefore, the point on the cornea measured by the ophthalmometer would be 2 mm. distant from the center of the cornea. Now the two chief radii of curvature at this point may be considerably different from the radii of curvature at the apex or center of the cornea. To simplify matters, we will assume that the radius of curvature changes in but one of the chief meridians, that of the vertical, while it remains unchanged in the horizontal.

Let the radius of curvature of the horizontal meridian at the center of the cornea be 8 mm., and that of the vertical meridian 7.61 mm. According to Javal's formula,

$$D = 1000\frac{(n-1)}{r},$$

the astigmatism at the center of the cornea in such a case is 2 D. Say, however, at a distance of 2 mm. from the center of the cornea the radius of curvature of the vertical meridian becomes slightly shorter, changing from 7.61 to 7.31 mm.

[1] The long axis of the cornea and the optic axis are considered as one and the same in practice.

in length, while the radius of curvature of the horizontal meridian remains the same as at the center of the cornea. According to the formula given above, the astigmatism at this point would be 4 D. The difference in the amount of the astigmatism at the two points would be clearly two whole diopters. Of course, this is a much exaggerated case, but it serves to illustrate how a large angle *alpha* may affect the readings of the ophthalmometer ; and how the astigmatism at the center of the cornea may vary from that at the point on the cornea intersected by the visual line.

As to the mooted question of the *amblyopia* which is usually present in strabismus cases, whether this amblyopia is congenital and causes the squint, or the squint causes the amblyopia from non-use of the eye (*amblyopia ex anopsia*), I shall have little to say, not having any new evidence to offer for either side.

Many authorities believe that the amblyopia present in most cases of strabismus is usually congenital, that is, *organic*, due to disease, and is the chief cause of the squint ; but that it is in a few cases acquired, *functional*, and is brought about in such cases by the non-use of the squinting eye. The mere fact, however, that the great majority of squints (convergent) develop between the ages of two and seven years, makes it quite evident that on account of the youth of the patient, it is almost impossible to decide if the patient has amblyopia before squinting, even if tests were attempted. Those holding this view, as they cannot depend on such examinations to decide the point, must judge by the result of the operation, the correction of the error of refraction and enforced use of the weak eye, to determine if the amblyopia is organic or functional. If organic, they say the amblyopia is not improved, while, if functional, it may be. And the fact, well established by experience, that the vision in the squinting eye, in the great majority of cases, is not and cannot by any means

whatever and however long persisted in be improved but very little, seems to lend weight to the contention that the amblyopia in nearly all these cases is organic and not functional. For, if not organic, they ask, why is not the vision improved when the eye is put in condition for seeing? Eyes with cataracts on them for years see after the cataracts are removed. Why is there not amblyopia in these cases from non-use, if non-use can cause an amblyopia, incapable of but slight or no improvement? [1]

Javal, of Paris, has, by the use of the stereoscope, by the enforced use of the weak eye to the exclusion of the good one for months at a time, etc., been able to secure improvement in vision in some of these apparently organic cases. But the majority of observers do not make such strenuous efforts, or persist in them for as long, as does Javal. After the improvement obtained in the first few weeks, the vision is rarely further improved; and, even though by the use of the stereoscope, and so forth, binocular single vision is restored, unless continued practice of the stereoscope is persisted in, this is lost again in many cases. Of course, where we have an intelligent patient, with the inclination and the leisure to keep up these exercises, it is entirely justifiable and should be encouraged.

Personally, I am of the opinion that the amblyopia in strabismus cases is usually functional, and due to the squint, though at one time I held the opposite view. That strabismus may cause, or, at least, be coincident with, amblyopia, there can be no doubt, as a few well-authenticated cases show.

Dr. Walter B. Johnson, of Paterson, N. J., has reported the most remarkable case of this kind, as follows: —

[1] Fuchs claims that the non-use of a cataractous eye does not make it amblyopic, simply because the retina is developed and practiced before the cataract (senile) is formed; but that in congenital cataract and squint cases the retina in the affected eye is often incompletely developed, hence amblyopia.

T. McK., aged nineteen, June, 1887, file forger, has been cross-eyed since three years of age, and states that during his recollection he had been unable with the left, squinting eye, to discern any object and define its character. He constantly fixes with the right eye.[1]

R. V. = $\frac{20}{15}$. L. V. = fingers at 6 inches. Fundus normal in each. June 13, the right eye was injured so badly with a file that it was enucleated the same day. June 18, L. V. = fingers 3 inches. Under continued practice with test letters and reading cards, by July 1, L. V. = $\frac{20}{15}$, and reads Jaeger No. 1 at 12 inches. The false fixation which he had was overcome. Three years later, V. = $\frac{20}{15}$.

"The peculiarities in the case," Dr. Johnson says, "are the length of time the amblyopia had existed (sixteen years), the return of perfect vision, and the shortness of time required for the vision to become normal."

A second remarkable case of this nature is reported by Dr. St. John Roosa.

Roosa's patient was a child aged seven years, from a squinting family, "who had no squint at time of examination, but was said to squint at times. R. and L. V. = $\frac{20}{20}$ H. 5 D. She accepted and wore + 4 D. In four years after, this child came with a fixed squint, by preference in the right eye, and the vision in that eye was reduced to $\frac{20}{100}$; while the left, the non-squinting eye, remained at $\frac{20}{20}$. The examinations, first and last, were made with great exactness, by competent men, — the late Dr. Edward T. Ely and my present associate, Dr. J. B. Emerson, — and I have no doubt of the truth of the observation. I advised an operation, but the case disappeared before I had the opportunity of making the crucial test of paralyzing the accommodation, and securing the best vision possible with glasses under such paralysis."[2]

[1] *Trans. Amer. Oph. Soc.*, July, 1893, Vol. VI, p. 551.

[2] *Treatise on Diseases of the Eye*, p. 549.

I may say, Roosa formerly held to the view that the amblyopia was congenital, but does so no longer.

Samuel D. Risley, of Philadelphia, reports a case of alternating amblyopia occurring in alternating convergent squint, with recovery in each eye. He also reports two other cases of amblyopia that became greatly improved. Harlan, Knapp, Holt, Javal, are others who have reported such cases.

Certainly these cases furnish *positive* evidence, and are not evidence of the negative nature, which the congenital cases must necessarily be. For this reason they are very convincing.[1]

Insufficiencies of the Ocular Muscles

Before proceeding to give illustrative cases of strabismus, I wish to speak briefly of insufficiencies of the ocular muscles, especially in their relation to refractive errors.

To Graefe belongs the honor of clearly distinguishing between muscular insufficiency and strabismus, and we are deeply indebted to him for his classical investigations in this field of work. Although some of his methods of testing the muscles were at fault, and have since been given up, yet his investigations put the subject on a scientific basis, and pointed the way for later investigators.

We are also greatly indebted to Alfred Graefe for his contributions on the subject of strabismus and muscular insufficiencies. It was he who emphasized the fact that before testing for insufficiencies of the ocular muscles we should first correct any refractive errors that might be, and often are, present in such cases, a point, by the way, of prime importance. Other distinguished investigators have added to the subject, but the name of the two Graefes stands out conspicuously.

[1] For a very valuable paper on this subject, see *Annals of Ophthalmology and Otology*, April, 1895, "An Argument for Amblyopia ex Anopsia in Convergent Strabismus," by W. Franklin Coleman.

The insufficiency of a muscle may rightly be called a *latent* strabismus. It may be of the slightest amount or very marked, and may develop into a true or manifest squint, especially when associated with large errors of refraction, or when prisms are prescribed and gradually increased in strength, thereby stimulating the stronger, antagonistic muscle to even greater exertion.

Muscular insufficiency of large, or even of moderate, degree, that is, of amount sufficient to give rise to asthenopic symptoms or to call for operative interference, not associated with troublesome refractive error or a general debility, is so rare as hardly to call for consideration at all, except for the satisfaction obtained in making a complete examination in every case. As for the insufficiencies that are associated with refractive errors, we know that these, as a rule, are relieved by simply correcting the refractive error. In the few cases that are not relieved by glasses alone, tonics, rest, and outdoor exercise, by those who can take it, will generally accomplish the desired result.

In the very limited number of cases that are not relieved by the above methods, and where the muscular insufficiency is so great as at times to cause diplopia and great annoyance, operative interference is called for in the form of a tenotomy — a complete tenotomy, and not the so-called graduated tenotomy. However, the cases that call for operative procedure are rare, as nearly every case of muscular insufficiency can be relieved with glasses, rest, outdoor exercise, and tonics. And I agree with Roosa when he says, "So long as there is no deformity, so long as the patient has no double vision, and can see to read well with the eyes, any operative interference, in my judgment, is utterly unwise, and founded on a false conception of the true condition of things."[1] In other words, I believe that no operation is justifiable in these cases until the insufficiency (which is a latent squint) develops into an actual manifest

[1] *The Post Graduate*, December, 1897, p. 725.

squint, periodic in nature, but, nevertheless, a true squint. Operative measures, even then, should not be undertaken, except in adults (sixteen years of age or over), and until all other means have failed.

There are a few cases of muscular insufficiency that are not relieved by any procedure whatever — glasses, tonics, rest, operations, or what not. These cases, Knapp says,[1] are benefited by the effects of age. He said he had been told this by Graefe, when working in his clinic, and that it had been borne out in his experience. In some way, increasing age seemed to harmonize the maladjustment between convergence and accommodation; which maladjustment, probably, was at the bottom of most of these cases. He thought the idea advanced by Dr. S. M. Payne, in one of his papers on this subject, of correcting the refractive error almost fully in those cases with excessive convergence, to be the correct one, and one giving more relief than any other procedure.

Perhaps it is not out of place here to give the meaning of the terms adduction, abduction, sursumduction; the methods of testing for insufficiencies of the ocular muscles, and what may be considered an insufficiency of action in a muscle as measured by prisms, the tropometer (Stevens), or otherwise; and the ratio or relative strength of a muscle as compared to the other muscles.

Adduction means, literally, to turn to or toward; and, as regards the median plane of the head, this would be inward turning of the eyes. It is accomplished chiefly by the internal recti muscles, assisted by the superior and inferior recti muscles.

Abduction means, literally, to turn outward. It is accomplished chiefly by the external recti muscles, assisted by the superior and inferior oblique muscles.

[1] In discussion of a paper read by Dr. Noyes, at the Oph. Sec., Academy Med., January 16, 1899.

Sursumduction means, literally, to turn upward. It is accomplished chiefly by the superior recti muscles, but is assisted by the inferior oblique muscles.

Deorsumduction means, literally, to turn downward. It is accomplished chiefly by the inferior recti muscles, but is assisted by the superior oblique muscles.

Methods of measuring the ocular muscles. — In my office I measure the strength of the different ocular muscles, that is, measure the adduction, abduction, sursumduction, with prisms, in the simplest way possible, as follows : With both eyes open, and directed to a candle flame twenty feet distant, I begin with the lowest prism in the case, with the edge or apex of the prism over the muscle to be tested, and gradually increase the strength of the prisms until the patient sees double. For example, to get the adduction, that is, to measure the strength of the internal recti, I begin with a prism 1°, apex inward, and gradually increase its strength till the patient sees double, or can no longer bring the images together after they are doubled ; for it often happens that a patient will see double when a prism of certain power is first placed in front of the eye, especially in measuring for adduction ; but, after a second or two, the images will come together. Another prism, a little stronger, is then to be tried, till a prism is reached that the patient cannot fuse the images with after they have once been separated. Say the patient overcomes a 14° prism, apex in, but that a 15° prism makes him see double. His adduction (prism convergence) is 14°.

To measure abduction, place apex of the prism outward over the external rectus muscle, and gradually increase its strength, till the patient can no longer see the candle single. For example, say he can overcome a 7° prism, but not 8°. His abduction is 7°.

To measure sursumduction, place apex of the prism upward, in front of the right eye, and increase its strength till the

patient sees double. For example, say the patient overcomes 3° prism, but not 4°. His right sursumduction is 3°. The left sursumduction is obtained by placing apex of the prism upward, in front of the left eye, just as in the right.

To measure deorsumduction, place apex downward, in front of the right eye, and increase its strength till the patient sees double, to get right deorsumduction ; and, to get left deorsumduction, place apex down, in front of the left eye, and increase its strength till patient sees double.

It is customary in practice to measure only the adduction, abduction, and sursumduction.

The old equilibrium test [1] of Von Graefe, that is, where a vertical diplopia is first produced in order to measure the strength of the muscles that move the eye in the horizontal plane, and a horizontal diplopia is produced in order to measure the muscles in the vertical plane, is very defective, and gives exaggerated results in nearly every case. This is due to the fact that the instant you produce a diplopia with prisms you at the same instant take away from the eyes the desire, and, to a certain extent, the power, of fusing the images in the two eyes. As the desire and the capacity of fusing the two images into one, that is, of obtaining single binocular vision, is the greatest stimulus the eyes have for keeping themselves balanced and in equilibrium, this equilibrium test, at the very outset, places the eyes in the most unfavorable condition for testing for equilibrium or balance. This test is to be condemned therefore. The simple prism tests for ascertaining the power of adduction, abduction, sursumduction, are much more reliable.

If I am not satisfied with the simple prism tests, I find the *amplitude of convergence* after Landolt's method. To get the

[1] This same test was later much used in America by Stevens and his pupils. Within the last few years, however, Stevens has invented an instrument for measuring the muscles, whereby he avoids diplopia in the beginning of the test.

maximum convergence, his method is to bring a narrow line of light (obtained by putting a metallic shield round a candle, and cutting a vertical slit in this shield three millimeters wide), toward the eyes, in the median plane, until the patient sees it double. Then he measures the distance from the eyes on a tape marked in centimeters. This number of centimeters divided into a hundred gives the number of meter angles of convergence of the eyes for the *near point*. For example, say the line of light[1] was brought to the distance of five centimeters when it doubled. Five divided into one hundred gives twenty, the number of meter angles of convergence for this distance (*punctum proximum*).

But, to get the *minimum* amount of convergence of which the eyes are capable, we must resort to measurement by prism divergence; for it is a well-known fact that most eyes can diverge slightly even after their visual lines are parallel. As the distant point of convergence (*punctum remotum*) is at infinity when the visual lines are parallel, it is manifest that, if the eyes can diverge further after this, the distant point, under such circumstances, must be beyond infinity; or, if prolonged backward, the visual lines would converge to a point back of the eyes, evidently not to be measured by tape or rule. In order to get this point, therefore, we measure the amount or angle of deviation that the eyes are capable of, as in measuring for abduction, by means of prisms with apex outward — the strongest prism the patient can overcome before seeing double, divided by two, representing the angle of deviation.[2] Then, from the size of the angle of divergence, according to a simple formula given by Landolt, we can calculate the distance of the distant point (*punctum remotum*) back of the eye.

[1] A black line on a white piece of paper serves the same purpose.

[2] The reason that the prism has to be divided by two is because a prism causes a deviation of only one-half the number of degrees in the prism. At least, this holds true in prisms of low or moderate degree of power.

As Landolt says: "It is not difficult to show the relation existing between the strength of any prism and the number of meter angles which expresses the deviation produced. For a base line (or distance between the centers of rotation of the two eyes) of 58 millimeters, as in children, a meter angle corresponds to $1° 39' 39''$ — say $100'$.

"The deviation produced by a prism may be taken as half its angle of opening, which is marked on each prism in our trial cases, or on the hand of the double prism. Therefore, a prism of $X°$ will produce a deviation of $\frac{X°}{2}$ or of $\frac{X \times 60'}{2}$. It is only necessary to divide this value by 100 in order to obtain the corresponding number of meter angles: $\frac{X \times 60'}{2 \times 100}$.

"This formula reduced to its simplest expression becomes $\frac{3X}{10}$, that is to say, *we have only to multiply the number of the prism by* 3, *and divide the prism by* 10, *in order to find in meter angles the deviation for a base line of* 58 *millimeters.*[1]

"When the prism is held before one eye only, as in the determination of the minimum of convergence by the double prism, its action is divided between the two eyes. The total deviation $\frac{3X}{10}$ gives for each eye $\frac{3X}{20}$. A prism of 6° produces a deviation of $\frac{18}{10} = 1.8$ meter angles. But if both eyes concur to neutralize this effect, each eye need only change its direction $\frac{18}{20} = 0.9$ meter angle. It is only when the prism of 6° is placed before each eye that the full result of 1.8 meter angles is obtained; always, of course, for a base line of 58 millimeters.

"When the base line is longer, for example, 64 mm., as in adults, the meter angle becomes $1° 50' = 110'$, and the formula becomes $\frac{3X}{11}$ for the deviation corresponding to the prism of $X°$,

[1] Italics mine.

or $\frac{3X}{22}$ for the effect produced on each eye when the prism is placed before one eye only."[1]

Say in the above case, when the positive convergence was 20 meter angles, the patient was able to overcome only 4° prism, apex outward. We will assume also that it is the case of a child with a distance between the centers of rotation of the two eyes of 58 mm. Landolt's formula would give $\frac{4 \times 3}{10} = 1.2$ meter angles of divergence (negative convergence). As we placed the 4° prism in front of but one eye, it equalled the strength of only 2° prism in front of both eyes, when our formula would be $\frac{4 \times 3}{20} = 0.6$ meter angle.

Now to get the *amplitude of convergence* we subtract the 0.6 meter angle of divergence (negative convergence) from the 20 meter angles of positive convergence which we got by actual measurement with the tape. This would give 20.6 meter angles as the amplitude of convergence in the above case.

Landolt has given 10.50 meter angles as the average amplitude of convergence, and I may say I have found his the most satisfactory way of measuring the convergence. Even when the measurement by means of prisms (prism convergence test) indicates an insufficiency, if the amplitude of convergence comes near the normal, I have found that simply correcting the error of refraction is all that is necessary in most cases, aided in some, however, by exercise and tonics.

Strength of the different ocular muscles as expressed in adduction, abduction, sursumduction; their direct and relative values. — Incidentally, I may remark here that our notions in regard to the strength of the different ocular muscles, as expressed in the terms adduction, abduction, sursumduction, and their rela-

[1] Landolt, *Refraction and Accommodation of the Eye*, p. 287.

tive values, have undergone some change since the publication of a paper by Bannister on the "Dynamics of the Ocular Muscles," in the *Annals of Ophthalmology*, January, 1898. Bannister measured the muscles in the eyes of one hundred soldiers in the United States army who were in rugged health; in fact, had to undergo the most rigorous physical examination before enlistment. They were required to read $\frac{20}{20}$ (Snellen) with each eye and without glasses before entering the service. So he had ideal subjects for testing the ocular muscles.

The results he arrived at vary widely from those laid down by most authorities, both as to the actual strength of the different muscles and of their relative values. As his experiments were made on absolutely healthy subjects, so far as physical examination was able to decide, on eyes with perfect vision and no asthenopia, and the tests made with much care, they must be given great weight. Bannister cites Risley's paper of similar measurements made on a series of twenty-five non-asthenopic persons, and says he is the only one other than himself to make such examinations in the healthy non-asthenopic subject. I may say, however, that Roosa,[1] in 1890, reported a series of 103 such cases, the examinations having been made for him by Dr. A. B. Deynard with the phorometer of Dr. Stevens, and after his method of testing. "Out of the 103 cases, 17, or sixteen per cent, were found to have muscular equilibrium; 84, or eighty-one per cent, had a want of muscular equilibrium, so-called heterophoria; of these 27, or twenty-six per cent, had deviation outward, exophoria, insufficiency of the interni; and 74, or seventy-one per cent, exophoria in accommodation; 16, or fifteen per cent, had deviation inward, or esophoria, insufficiency of the externi; 7 had esophoria in accommodation; 11, or ten per cent, had hyperphoria, a tendency of the right or left visual line upward; 24 had hyperphoria in accommodation. A reëxamination of five

[1] *Med. Record*, April 19, 1890.

of these patients all showed a change in the muscular examination from that found at first. This is an important observation, since it proves, as asserted by Starr and others, that the muscular power in the same eyes is not fixed, but variable."

Adduction, as measured by prisms (prism convergence), the common method pursued in office practice, bases out before the eyes, amounts for the distance vision to from 35° to 50°. At least this is the standard given by most authorities. Bannister, in his experiments on one hundred healthy, non-asthenopic subjects, gives the average adduction as only 14.1°. He says in regard to it: "I am perfectly willing to place myself upon record as asserting that the teaching of the authorities that healthy eyes should show upon demand a prism convergence for distance of 30°, or 35° to 50°, is absolutely misleading and erroneous. In my series of examinations the highest amount of adduction for 6 meters reached was 26°, and this amount could only be obtained in *one case*, and that, too, only after most careful effort. We are told that in our office consultations our patients should show this amount of adduction (30° or 35° to 45° or 50°), and that if they do not exhibit it *we must consider their convergence to be weak*. If we accept as true the standard given above, *every one of my healthy cases should be charged with convergence insufficiency*."

He, however, remarks that by prism practice most, if not all, of these could be made to show an adduction of 50°. "But," as he again says, "that is not the point at issue." It is the *first* test, and not when they have had previous tests, prism practice, if you please, of which he speaks.

Abduction, as measured by prisms (prism divergence), for distance amounts, as a rule, to 8°, according to the older standards. Risley gives the same amount for healthy non-asthenopic subjects. Bannister gives 7° as the average abduction for his one hundred healthy soldiers, but in many of his cases it was considerably less. In this connection he calls

attention to the claims made by Noyes, Duane, and others that abduction should not fall below 6° for the distance, and that an abduction of less than 5° will in most cases be pathological. In other words, that an insufficiency of the external recti is present.

Bannister says, "If these views are correct, twenty-two, or at least seventeen, of my absolutely healthy cases, would fall in the pathological class." He does not believe them to be in this class, however, for every one of the twenty-two cases showed perfect muscle balance for the near point, and only nine a want of balance of the muscles for the distance, and that in only a slight degree.

The same author also explodes the old idea that for the *near point* we may expect an insufficiency of the internal recti of about 5° prism, and that such a condition is physiological (Duane). In fact, he demonstrates that muscle balance is more frequent for the near point than for the distance, for in his one hundred cases he found perfect muscle balance for the distance in but sixty cases, while for the near point it was present in eighty-two cases. Moreover, he showed in the thirteen cases that had a divergence excess for the distance that eleven of them had perfect muscle balance, and only two of them showed slight diverging tendency for the near point. This is just the reverse of what would be expected according to the old standards, and can be explained only on the ground, Bannister thinks, "that orthophoria is the physiological state for the near:" and this, "notwithstanding the opposite opinion held by such eminent authorities."

In regard to the ratio between adduction and abduction, or their relative strength as measured by prisms, Bannister thinks that there cannot be any definite relation fixed; and is of the opinion that older standards of 6 to 1, or 7 to 1, without previous training of the convergence with prisms, is much too high. His own results would indicate that relation in healthy,

non-asthenopic subjects to be about 2 to 1, since the average adduction in his cases was 14.1°, while the average abduction was 7°.

Sursumduction, as measured by prisms, base down, amounts to 2° to 4°.

Deorsumduction, as measured by prisms, base up, amounts to 2° to 4°.

Bannister, in his healthy subjects, gave 2° as the average, both of sursumduction and deorsumduction, and says in regard to their relative strength, "It seems well settled, also, that the power in each direction of the vertical plane is *about the same*, *and that deorsumduction should not be expected to exceed the antagonistic function as held by some.*"

Since I have quoted so liberally from Bannister's paper,[1] I give his conclusions, which, since they are based on the examinations made in perfectly healthy subjects with non-asthenopic eyes, must be admitted to form a good standard for abnormal conditions: —

"1. The degree of *adduction* (prism convergence) given by most writers as proper for 6 meters, *cannot be reached by healthy eyes except after practice in the use of prisms.* Hence the standard is too high for attainment in the first office examination, and hence the method *of measuring the convergence by adductive prisms is unreliable and misleading.*

"2. That the *prism convergence* for *near* (33 centimeters) is also misleading, *and is not an accurate test of the real power of convergence.*

"3. That the determination of the *punctum proximum of convergence*, and the calculation of the *maximum convergence* after the method of Landolt, are the only true tests of the *real power of convergence*, or the *positive convergence.*

"4. That, contrary to the generally received views, *abduction* (prism divergence) for distance can fall well below 6° in

[1] *Annals of Ophthalmology*, St. Louis, January, 1898.

healthy eyes, and that, consequently, *it is wrong to assume upon this basis alone that such cases are pathological.*

"5. That there exists in healthy eyes no positive, definite relation between *prism convergence and prism divergence* for distance, and that it is not correct to claim that such eyes should *without practice with prisms* show at 6 meters a ratio between these functions of 3 to 1, or 7 to 1, in favor of convergence, not permitting abduction to fall below 6°.

"6. That we may expect sursumduction and deorsumduction for distance to be about the same in degree; in about 70 per cent of healthy eyes each function reaches 2° (prism) in amount.

"7. That in healthy eyes *orthophoria* exists in about 60 per cent of the cases *for distance*, and in about 82 per cent *for near*, and that *it is wrong to hold that orthophoria for near is abnormal, and to be viewed with suspicion.*

"8. That in about 40 per cent of *healthy individuals* who have never had a symptom of eye trouble there may be found a slight *heterophoria for distance*, and that, therefore, we should not assume that *every patient* showing a slight degree of imbalance is on that account alone in a serious condition."

The mere fact, however, that the examinations from which these conclusions of Bannister are drawn were made on eyes with little or no refractive error, without asthenopic symptoms, and in healthy subjects, must be borne in mind: for it may be stated as a general principle that hypermetropic errors of refraction favor convergence, while myopic favor divergence, of the eyes. Hence, we may find a predominance of the one or the other, accordingly as the eye is hypermetropic or myopic; and this should be remembered when refractive errors are present.

But, taking refractive cases as they come, I must say my experience as to the strength of the muscles, actual and relative, more nearly agrees with that of Bannister's than with the ordinary standards as given in the text-books of to-day.

As a rule, strabismus cases should not have glasses fitted until three years of age, for under this age they can seldom be made to wear the glasses; or, if they do wear them, be made to look *through* them; they, most of the time, looking under or over them. Then again, the danger of a young child breaking the glasses and injuring the eyes is not to be forgotten. I have fitted two cases of glasses at three years of age; but, in each case, the child was very tractable, and wore the glasses as directed by the mother. Dr. Dennett, of this city, has, I believe, fitted children at the tender age of two years.[1]

Of course, as soon as the eyes are adjusted to glasses they are in a better condition to be used together, and the stimulus to single binocular vision is much enhanced, if amblyopia is not too marked.

Incidentally, in this connection, I might say that, with rare exceptions, no operation should be done on a squinting eye in a child under four years of age; and, as a rule, it is safer to wait till the patient is five or six years old. It is a well-established fact that many children "grow out" of a convergent squint. I have seen several patients who gave a history of squinting in childhood, but who had perfectly straight eyes when they came under my care in later life, and without

[1] In reply to a note from me, I received the following letter from the doctor: —

"Dear Doctor Davis, —

"In 1889 I had a little girl for a patient who was fourteen months old, and who had had a well-marked convergent strabismus for some weeks. She had by ophthalmoscopic examination, — upright image. — Hm. + 2. O. U.

"I ordered glasses, and asked the mother to see if she could make the child wear them. I have not seen the child since, but the mother told me that the glasses were worn most of the time for two weeks, when the squint disappeared, and the baby was allowed to go without them.

"The mother was an intelligent woman, and I believed her.

"Yours, etc."

having had any operation on the eyes.[1] While writing this chapter, two such cases have come under my care, both of whom had squinted in childhood, but both had recovered from it without glasses and without operation. In each case there was a high degree of compound hypermetropic astigmatism, with marked amblyopia in the eye that had squinted. Both cases are reported in this chapter farther on.

Dr. Roosa tells me he has the history of at least one hundred cases who had squinted in childhood, but subsequently recovering without operative procedure. In fact, testimony of like character is to be had on all sides; so it behooves us, in strabismus cases, not to be in too great a hurry about operating, especially in convergent strabismus. It is best first to begin by fitting the patient correctly to glasses under a mydriatic, and letting these glasses be worn continuously for a number of months, or years, if the patient is very young, before operating.

For measuring the amount of strabismus, there are two or three very simple methods: (1) By means of a very simple instrument, the strabometer of Laurence, represented in the cut below, the deviation of the eye can easily be measured. This instrument is numbered in millimeters from the center, 0, laterally in each direction. By placing this instrument directly beneath the deviating eye, while the good eye is fixed on some

[1] I have seen one case, in fact, within the year, where a convergent strabismus developed into a divergent strabismus, and without any operative procedure whatever. The patient, a gentleman of much intelligence, aged thirty-five years, gave a history of marked inward squinting of his left eye when a child which got well of itself, without glasses and without operation, by the time he was twelve years of age. Although he always saw poorly with the left eye, he did not have glasses fitted till twenty-one years of age, which glasses he has worn since. About three years ago he noticed that his left eye turned outward at times, and for the last few months continually. There is a divergence now of 10°. R. V. = $\frac{20}{30}$: $\frac{20}{20}$ W. + 1 D. + .75 cyl., 90°; L. V. = $\frac{5}{200}$: $\frac{20}{200}$ W. + 3 D. + 1 D. cyl., 90°. Binocular single vision is absent. There is no lesion in the fundus of either eye. This is the only case of the kind that has come under my observation.

distant point, and noting the number of millimeters distance the center of the cornea is from the center of the instrument, we at once ascertain the amount of the deviation in millimeters. As each millimeter of deviation represents roughly an angle of 5°, we can reduce the linear deviation to an equivalent expressed in degrees, by simply multiplying the number of millimeters of deviation by five; for example, say the linear deviation was three millimeters, this reduced to degrees would be 15°, and so on.[1]

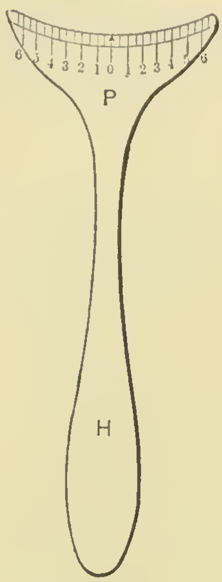


FIG. 101.—Strabometer of Laurence.

(2) The extent of deviation or squinting of an eye may be measured with the perimeter. Place the patient in front of the instrument, with the deviating eye in line with the center of the arc, just as if to take the field of vision. Leave both eyes open, and have the good one directed to a distant object (20 feet) directly in front; then carry a candle along the arc of the instrument until the image of the flame is at the center of the cornea of the deviating eye. The position of the candle on the arc marks the number of degrees of deviation.

(3) A simple method, without the use of any instrument whatever, is as follows: Have the patient look at a distant object directly in front of him, then make an ink-dot on the lower lid of the deviating eye, directly below the outer margin of the cornea; also a dot on the lid just below the outer margin of the cornea of the straight eye. Now cover the straight eye with a card, and let the patient fix the object with the bad or crooked eye. Of course, the eye will have to move from its original position to do this, and the good eye back of the card will squint as the bad eye had when uncovered. Again mark

[1] Perhaps each millimeter of deviation would be more nearly represented by an angle of $5\frac{1}{2}$°, rather than the even number 5°.

the position of the outer margin of the cornea on the lower lid of the bad eye; also the position (back of the card) of the outer margin of the cornea of the good eye on the lower lid. The deviation in each eye will be found to be exactly the same. That in the bad eye is called the *primary* deviation, that in the good eye the *secondary* deviation. The distance between the two dots on the lids will be the amount of deviation. To get it in degrees, multiply the number of millimeters by 5; for example, say the distance between the dots on each side is 4 millimeters. This multiplied by 5 gives 20, the number of degrees of deviation.

If, as sometimes happens, the power of fixation is lost in the squinting eye, even when the good eye is covered, this last test cannot be made. The approximate amount of the deviation can be determined in such cases by having the patient look at a distant object directly in front of him, then measure the distance between the external canthus and the outer edge of the cornea in each eye. The difference between the two amounts is the extent of the deviation of the squinting eye (Fuchs).

For more complete tests for determining the amount of deviation or squint in an eye, and for the indications for operating on such eyes, I must refer the reader to the larger text-books. An intimate knowledge of the anatomy and physiology of the muscles of the eye, as well as an acquaintance with the refractive conditions, is necessary for a full understanding of the subject.

CASE XCV. *Convergent strabismus left eye: Simple hypermetropia both eyes; Cure by means of glasses and a mydriatic.* — July 7, 1892, Hugh G., aged four years, in good health, was brought to me by his mother on account of the left eye turning toward the nose. The eye has squinted since he was a baby. He had diphtheria when one year of age, but the eye turned before he had diphtheria. The patient has a twin sister and

a younger brother, whose eyes are perfectly straight. Father and mother's eyes are straight.

Ophthalmometer. — Astigmatism with the rule, .50 D., axis 90° + 180° – each eye. As the patient was too young to test with the test cards, I made no attempt at subjective examination.

Ophthalmoscope. — H. 2 D. right eye; H. 4 D. left eye. Ordered atropine solution, 2 gr. to ℥i, to be used three times a day for one week. Before instilling the atropine solution, I measured the amount of deviation, and found it to be between 15° and 18°. Under atropine, the ophthalmoscope showed H. 4 D. right, and H. 5 D. left. The retinoscope confirmed this. A + 3.50 D. spherical glass right, and + 4.50 D. left, were ordered for constant wear; and one drop of the atropine solution, in each eye, once a day, was continued for two weeks. At the end of that time the eyes were much improved; atropine, one drop every other day, was used for two weeks longer, then it was discontinued altogether. At the end of six months the patient had perfectly straight eyes with the glasses on. If the glasses were removed, the patient would turn the left eye inward, but not as far as when first seen.

I have seen this child from time to time for the last seven years, and the eyes remain perfectly straight with glasses, but have a tendency to turn for the near point unless the glasses are on.

When the patient arrived at the school age and knew his letters, I tested both eyes carefully for acuteness of vision, to see if any amblyopia was present in the eye that had squinted. The vision in each eye was $\frac{20}{30}$ (Snellen) with his glasses on. If he ever had amblyopia in the left eye, it had disappeared with use and the aid of the glasses. Single binocular vision is present.

Operative proceedings in this case when first seen would have been unwise. The motility of the eye, the acuteness of

vision in each eye (when it can be taken), the kind of squint, alternating or fixed, are all factors which should be weighed before any operation should ever be undertaken.

The ophthalmometer was a valuable means for eliminating the factor of corneal astigmatism at the outset of the case. Retinoscopy was of value, also, as atropine had to be used. In fact, it is in just such cases that these objective tests are of such great importance.

CASE XCVI. *Periodic convergent strabismus right eye; Simple hypermetropia each eye; Cure effected in three months by means of glasses alone.* — November 27, 1898, Wm. M., aged seven years, in good health, came to the clinic of Drs. Lewis and Van Fleet, because of squinting of the right eye inward at times for the last year. None of his family is cross-eyed. As is often the case, the mother attributes the cause to a fall on the head when the patient was a baby, although the eye did not begin to squint till he was about six years of age. The right eye deviates inward about 15°.

Ophthalmometer. — Astigmatism with the rule, 1 D., axis 90° + or 180° – in each eye.

Test cards and trial lenses. —

$$\text{R. V.} = \tfrac{20}{20} : \tfrac{20}{15}\ \text{W.} + .50\ \text{D. cyl., } 90°.$$
$$\text{L. V.} = \tfrac{20}{20} : \tfrac{20}{15}\ \text{W.} + .50\ \text{D. cyl., } 90°.$$

Reads Jaeger No. 1 from 4 to 12 inches.

Ophthalmoscope. — H. 2 D. in each eye.

Ordered atropine solution, 2 gr. to ℥i, to be instilled, three times a day, for four days, and to return for a second test.

Second test: ophthalmometer shows astigmatism with the rule, .50 D., axis 90° + or 180° – in each eye.

Test cards and trial lenses. —

$$\text{R. V.} = \tfrac{20}{70} : \tfrac{20}{20}\ \text{W.} + 3\ \text{D.}$$
$$\text{L. V.} = \tfrac{20}{70} : \tfrac{20}{20}\ \text{W.} + 3\ \text{D.}$$

Ophthalmoscope. — H. 3 D. in each eye.

A plus 3 D. sphere was ordered for each eye, to be worn steadily. In three months' time this patient ceased to squint altogether, although he went to school, and used the eyes for close work.

It is hardly necessary, I suppose, to say that a periodic squint, in young subjects especially, should not be operated upon. Certainly not until glasses have been given a thorough trial: aided, if need be, by having a weak solution of atropine instilled into the eyes, once a day, for a few weeks at a time; then intermit, and repeat once or twice. Covering up the good eye for half an hour, once or twice a day, is valuable in these cases. The stereoscope is valuable also. If, after a few weeks, or months at furthest, the squint is not improved, but grows worse, becoming a permanent squint, an operation is to be considered, and no more time should be wasted.

In the case just reported, the ophthalmometer showed astigmatism of 1 D., before the mydriatic was used, and the patient accepted .50 D., the correct amount after deducting .50 D., as is ordinarily done in astigmatism with the rule. After using the mydriatic, however, the instrument showed only .50 D., and the patient accepted only a spherical glass, as is customary when there is only .50 D. of corneal astigmatism with the rule. This discrepancy is to be explained in one of two ways: first, in the first test there might have been an error in observation, which seems unlikely, as the patient accepted + .50 D. cyl., 90°; second, when the mydriatic was used it relaxed the accommodation, the convergence was relaxed at the same time, and this relaxation of the convergence took some pressure off the horizontal meridian of the cornea, and, in that way, lessened the astigmatism, perhaps. I rather incline to the latter opinion. That the straight muscles do exert some influence on the curvature of the cornea is proved by a case reported by me in the *Manhattan Eye and Ear Hospital Reports*, 1895, p. 49.

A favoring factor in this case, in aiding the eyes to become straight without operation, was the fact that there was no amblyopia present in either eye, for this reason the fusion of the images of the two eyes was greatly facilitated, and the desire for single binocular vision increased. Single binocular vision was restored in this case.

Even where the squint is constant, but where the patient squints first one eye, then the other, at will, and without the necessity of covering either eye, — the so-called alternating squint, — the visual acuity is apt to be the same, or nearly the same, in each eye, and to be very good, $\frac{20}{50}$ or better. In such cases, the chances for cure with glasses alone are much better than where amblyopia is present in one eye.

Case XCVII. *Convergent strabismus right eye; Compound hypermetropic astigmatism both; Amblyopia both, but more marked in the right; Glasses and one operation necessary for a cure.* — September 11, 1894, Grace C., aged eight years, came to the clinic of Drs. Lewis and Van Fleet because of squinting of the right eye, which has squinted constantly for four years. She has not had treatment of any kind thus far.

Ophthalmometer. — Astigmatism with the rule, 1 D., axis 90° + or 180° − each eye.

Test cards and trial lenses. — (Under atropine mydriasis).

R. V. = $\frac{20}{200}$: $\frac{20}{100}$ W. + 4 D. + .50 D. cyl., 90°.

L. V. = $\frac{20}{70}$: $\frac{20}{40}$ W. + 3 D. + .50 D. cyl., 90°.

Ophthalmoscope. — H. 5 D. right eye; H. 4 D. left eye.

Ordered the glasses that were accepted under atropine, which were worn continuously for six months, but the squint remained. At the end of this time a tenotomy of the right internal rectus was done. The eye was made perfectly straight with the operation, and by continued use of the glasses was kept straight, although single binocular vision was not restored.

It will be noticed that the amblyopia was marked in the right or squinting eye, while it was present to a moderate degree in the non-squinting eye. The ophthalmometer in such cases as this is very useful, for with so marked amblyopia, as was present in the right eye, glasses do not improve the vision much, no matter what glasses are given, yet it is important to give the correct glass. If we can measure the astigmatism in such cases, and have that important factor satisfactorily disposed of, it greatly facilitates matters.

CASE XCVIII. *Convergent strabismus right eye; Large amount of compound hypermetropic astigmatism in each eye, more marked in the right eye; Amblyopia in each; Cured by glasses and one operation.* — October 9, 1894, J. R., aged nine years, came to the clinic of Drs. Lewis and Van Fleet to have the right eye straightened. The right eye has turned inward since he was a small child, and now has a squint of 20° or more. He can fix with the squinting eye when the good one is covered. None of the family but himself ever had "cross-eye."

Ophthalmometer. — Astigmatism with the rule, 2 D., axis 120° + or 30° − right eye; 1.50 D., axis 60° + or 150° − left eye.

Test cards and trial lenses. —

R. V. = $\frac{20}{200}$: $\frac{20}{70}$ + W. + 3 D. + 1.50 D. cyl., 120°.

L. V. = $\frac{14}{200}$: $\frac{20}{70}$ + W. + 4 D. + 1 D. cyl., 60°.

Ophthalmoscope. — H. 3 D. at 120° and H. 5 D. at 30° right eye; H. 4 D. at 60° and H. 5 D. at 150° left eye.

Ordered atropine solution, 4 gr. to ℥i, three times a day for four days.

Test under atropine: ophthalmometer showed the same reading as in the first test.

Test cards and trial lenses. —

R. V. = $\frac{10}{200}$: $\frac{20}{70}$ W. + 4 D. + 2 D. cyl., 120°.

L. V. = $\frac{7}{200}$: $\frac{20}{70}$ W. + 5 D. + 1.50 D. cyl., 60°.

Ophthalmoscope. — H. 4 D. at 120° and 6 D. at 30° right eye; H. 5 D. at 60° and H. 6 D. at 150° left eye.

Two days later a third test was given, the atropine having been stopped. The ophthalmometer showed the same reading as on previous occasions. With the test cards and trial lenses the patient accepted the same spherical glass as when under atropine, but one-half diopter less of astigmatic correction. Ordered: —

+ 4 D. + 1.50 D. cyl., 120° right;

+ 5 D. + 1 D. cyl., 60° left.

Two days later a tenotomy of the right internal rectus muscle was done. With the glasses on, the eyes were perfectly straight. One month later there was a slight convergent squint in the right eye, but not enough to notice, except on close inspection.

No further operative procedure was deemed necessary. Glasses were ordered to be worn continuously. The patient did not have single binocular vision.

Case XCIX. *Marked convergent strabismus in each eye, more pronounced in the right (50° right and 25° left); Power of fixation lost in the right, and in the left motion outward is limited also, the patient carrying her head to the left in order to see straight ahead: small amount of hypermetropia; Cured by tenotomy of the internal recti muscles, and advancement of the right external rectus.* — Violet J., aged four and one-half years, was brought to my clinic at the Post-Graduate School, in October, 1897, by her mother, to have the child's eyes straightened, because the children at the kindergarten made fun of her. The patient's eyes have both turned inward since she was a baby. At present the right eye turns far in (50°) and cannot

be turned out to the median line. The left eye turns inward 25°, and motion outward is limited, so much that the patient carries her head to the left in order to see objects straight ahead. Fuchs, quoting Arlt, explains the oblique position of the head in such cases as follows: "As convergence is an associated movement of both interni, this impulse affects both at once, so that, owing to their excessive contraction, the visual lines would cross in front of the object; but as the patient then would fail to have direct vision of the object with either eye, he turns his head a little to one side. He thus gets the object into the line of vision, *g*, of one, and that the better eye (*L* Fig. 102), while the line of vision, *g′*, of the other eye shoots off so much the farther from the object. Thus the patient secures fixation with one eye at all events, although both interni are still strongly contracted. It is owing to the last-named fact that the increase in the power of adduction develops in the course of time in both eyes. By this fact, too, is explained the *oblique position* of the head in those affected with convergent strabismus — such persons carrying the head turned toward the side of the healthy eye."[1]

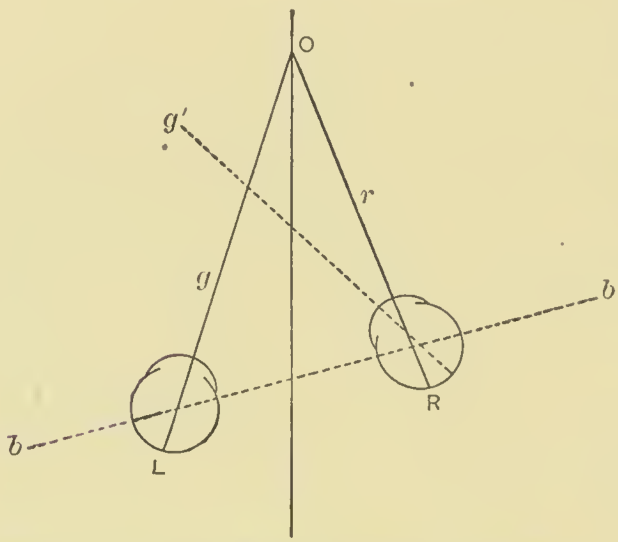


Fig. 102. — (After Fuchs.) Showing oblique position of the eyes and head in convergent strabismus of both eyes.

The right eye in the present case could not be made to fix when the left was covered, the marked contraction of the internal recti preventing; and, even with the left, the head had to be turned in order to fix the object.

[1] Fuchs, *Text-Book of Ophthalmology*, p. 573.

The external movements of both eyes were not only limited relatively as compared to the internal movements, but actually, as already remarked above.

Ophthalmometer. — Astigmatism with the rule, .50 D., 90° + or 180° − left eye. The right eye could not be measured with either the ophthalmometer or retinoscope, because the patient could not turn the eye out far enough; and to measure the left eye, the patient had to turn her head to the left in order to give a front view of it.

Ophthalmoscope. — H. 2 D. in each eye.

As the child did not know her letters, no subjective test was tried. Atropine was ordered, and after three days a second test was made. The ophthalmometer gave the same reading as before. The ophthalmoscope showed H. 2.50 D. each. Ordered + 2 D. sphere for each eye. I then did a tenotomy on each internal rectus. The eyes were not straightened with this, but I refrained from making an advancement of the right external rectus at this time to see how much effect the tenotomies would have. Atropine was used once a day for the next month, and the glasses were worn continuously. After six weeks the left eye was straight, but the right still turned in considerably, 20°, so a second tenotomy of the right internal rectus, with advancement of the right external rectus, was done by my assistant, Dr. J. R. Nelson. The squint was over-corrected slightly, on purpose, and for the first few weeks after the operation it was noticeable, especially with the glasses on. The glasses were ordered discontinued. Six months after the advancement the eyes were perfectly straight, and the child was ordered to leave off the glasses.[1]

This patient was younger than I like to operate on for

[1] The reason for taking the glasses off in this case is obvious. The squint having been slightly over-corrected by the advancement, by taking off the glasses the patient had to use her accommodation, and this stimulated convergence with the result that the eyes were held perfectly straight.

squint, but as the strabismus was so pronounced and in each eye, and because she was an object of ridicule by her school companions, I deemed it best to operate. At this writing, eighteen months after the advancement, the eyes are still parallel, and the patient carries her head straight. She does not have single binocular vision, however, as the right eye is very amblyopic, as shown by tests with figures which the child now knows.

Case C. *Divergent strabismus right eye; Antimetropia; Compound myopic astigmatism right and compound hypermetropic astigmatism left eye; With glasses the squint was relieved and single binocular vision obtained for distant vision, but not for near.* — June 7, 1897, Mrs. A. M., aged thirty-one years, in good health, has always had trouble with her eyes, and when she reads or sews the eyes ache. The right eye has turned outward at times for the last fifteen years.

Ophthalmometer. — Astigmatism with the rule, 2 D., axis 80° + or 170° – right eye; .50 D., axis 100° + or 10° – left eye.

Test cards and trial lenses. —

R. V. = $\frac{18}{200}$: $\frac{20}{40}$ W. – 1 D. – 1.50 D. cyl., 170°.

L. V. = $\frac{20}{40}$: $\frac{20}{20}$ W. + .25 D. + .25 D. cyl., 100°.

Reads Jaeger No. 1 from 6 to 15 inches with the left eye. The patient does not use the eyes together for reading, either with or without the glasses. For distant vision with the glasses on the patient has single binocular vision, as shown by the test with prisms, to wit: ad. 10°, ab. 7°, sur. R. & L. 2°. Without the glasses she does not have single binocular vision.

Ophthalmoscope. — M. 3 D. at 75° and M. 1 D. at 165° right eye; H. 1 D. left eye.

Because of a mild conjunctivitis alum was applied to the lids and an astringent wash prescribed. One week later a second test was made.

Second test: *Ophthalmometer.* — Astigmatism with the rule, 2.50 D., axis 75° + or 165° – right eye; .75 D., axis 120° + or 30° – left eye.

Test cards and trial lenses. —

$$\text{R. V.} = \tfrac{20}{200} : \tfrac{20}{15} - \text{W.} - .75\text{ D.} - 2\text{ D. cyl., } 165°.$$

$$\text{L. V.} = \tfrac{20}{30} : \tfrac{20}{15} - \text{W.} + .25\text{ D. cyl., } 120°.$$

Reads Jaeger No. 1 from 6 to 15 inches right, and Jaeger No. 1 from 4 to 10 inches left eye, but does not use the eyes together. The angle *alpha* is small in the right eye, being 2° positive, while it is 4° positive in the left eye.

A third test agreed with the second, and – .75 D. – 2 D. cyl., 165° right, and + .25 D. cyl., 120° left, were ordered for constant wear. These glasses gave immediate relief from the asthenopia from which the patient suffered. One year later I saw the patient again; she was entirely comfortable, the eyes were straight, and she had single binocular vision for distance, but not for near; ad. 15°, ab. 6°, sur. R. & L. 2°.

For a very interesting case of convergent strabismus in the myopic eye of an antimetropic case, which was corrected by glasses alone, see Case LXX in Chapter VI.

CASE CI. *Divergent strabismus right eye; Simple hypermetropic astigmatism in both; Correction of refractive error; Tenotomy right external rectus; Relief.* — January 4, 1894, Henrietta M., aged thirty-three years, in fairly good health, gives the following history: —

Four years ago she had an abscess at the lower end of the spine; a year later had part of the coccyx removed, and six months later some more of the coccyx removed. By these two operations the spinal trouble was cured. In the meantime, however, her eyes began to pain her when she did close work of any kind, and she had glasses fitted, which relieved her for a time, but they do so no longer. She says if the

right eye diverged at that time that the doctor did not tell her of it. At the present time the right eye diverges between 5° and 10°. She is wearing + 75 D. cyl., 90° each.

Ophthalmometer. — Astigmatism with the rule, 1.25 D., axis 90° + or 180° – each eye.

Test cards and trial lenses. —

$$\text{R. V.} = \tfrac{20}{20} - : \tfrac{20}{15} - \text{W.} + .75 \text{ D. cyl., } 90°.$$

$$\text{L. V.} = \tfrac{20}{20} - : \tfrac{20}{15} - \text{W.} + .75 \text{ D. cyl., } 90°.$$

Reads Jaeger No. 1 from 6 to 18 inches with the left eye, and the same with the right if the left is covered. Angle *alpha* equals 2° each eye, positive.

Ophthalmoscope. — H. 1 D. at 90° and H. 2 D. at 180° each eye.

A second test resulted in the patient accepting the same glasses as at first; and since they corresponded exactly with the glasses she was already wearing, + .75 D. cyl., 90° each, I did not change them; neither did I put this patient under the influence of a mydriatic, as is my custom in squint cases, because the patient had a *divergent* squint with *hypermetropia.* The mydriatic would have increased the squint, as would also the plus spherical glass fitted under its influence. Since the divergent squint had apparently developed while she was wearing the cylindrical correction, and as she was a seamstress and wanted relief from a diplopia which manifested itself frequently in the last few weeks before coming to me, I advised an operation, to which she consented. Accordingly, on January 10, 1894, I did a complete tenotomy of the right external rectus muscle, making a small opening in the conjunctiva and Tenon's capsule, but not dissecting back along the muscle and up and down, as usual, as I did not want to have an over-effect.

Immediately after the tenotomy, and for three or four days following, the right eye as measured by prisms converged 10°.

At the end of two weeks, not only were the eyes perfectly straight and single binocular vision present, but the patient could use her eyes with perfect comfort.

January 4, 1898, four years later, this patient came to me again complaining of headaches, pains in the eyes, and an occasional diplopia, especially for near points. On examination, the right eye showed a divergence of perhaps as much as 5°, but after covering and uncovering the eye several times the squint would disappear. I tested the eyes again and found an increase in the amount of the astigmatism. The ophthalmometer showed astigmatism with the rule, 2 D., 90° + or 180° − right, and 1.50 D., 90° + or 180° − left eye. The patient accepted + 1.25 D. cyl., 90° right, and + 1 D. cyl., 90° left. It will thus be seen that the corneal astigmatism had increased .75 D. in the right eye, and .25 D. in the left. The patient by the subjective test accepted .50 D. more in the right and .25 D. in the left, than four years previously, and the glasses were ordered. I gave her full doses of sulphate of strychnine also, and after about six weeks' time the patient was again comfortable, and able to see and read. This was over a year ago, and at the present time the glasses enable her to do her work with comfort. Single binocular vision is present.

Case CII. *Divergent strabismus right eye; Myopia of high degree right and moderate degree left; Glasses; Tenotomy right external rectus without advancement of the internal rectus; Cure.* — December 1, 1898, E. H., aged twenty, has been near-sighted since a small child, was brought to me by her mother to have her right eye straightened. She has pains in the eyes at times. She is now wearing − 5 D. spherical glass before each eye. Not only does the right eye diverge about 20°, but there is a slight horizontal nystagmus present. The patient is extremely nervous.

Ophthalmometer. — Astigmatism with the rule, .50 D., axis 90° + or 180° − right eye; .75 D., axis 90° + or 180° − left eye.

Test cards and trial lenses. —

$$\text{R. V.} = \tfrac{4}{200} : \tfrac{20}{200}\ \text{W.} - 13\ \text{D.}$$

$$\text{L. V.} = \tfrac{10}{200} : \tfrac{20}{30}\ \text{W.} - \ 7\ \text{D.}$$

Reads Jaeger No. 1 at 10 inches with the left eye.

Ophthalmometer. — M. 14 D. right eye, with a posterior staphyloma; M. 8 D. left eye.

Second and third tests resulted in the patient accepting the same glasses as found at the first test. Ordered − 9 D. right, and − 7 D. left. I did a complete tenotomy of the right external rectus. With the aid of the glasses and the simple tenotomy, the patient has perfectly straight eyes, though not single binocular vision. Usually these divergent squints, especially in myopic eyes, require advancement of the internal rectus in addition to tenotomy of the external rectus. Four months after operation, the patient still had straight eyes.

Case CIII. *Convergent strabismus right eye marked, and to a moderate degree in the left; Hypermetropia right, compound hypermetropic astigmatism left eye; Glasses; Tenotomy of internal rectus of each eye; Cure.* — December 1, 1898, M. H., aged nineteen years, in good health, a sister of the patient just reported above, with myopia and divergent squint in the right eye, was brought to me at the same time as her sister to have her eye straightened. Her mother tells me that her eyes have turned since she was four years old, and attributes it to a scare.

In connection with these two cases, it is an interesting etiological factor to know that the mother is antimetropic, being highly myopic in the right eye (13 D.), exactly the same as the myopia in right eye of the myopic daughter with divergent squint, and is slightly hypermetropic in the left eye, about .50 to 1 D. The father is hypermetropic, as is also a younger sister. Neither father or mother ever squinted, and

the mother never wore glasses till forty-three years of age, which I gave her for reading (see case, Chapter XI). The question is: Did one daughter inherit one eye of the mother, and the other daughter the other eye? It is a striking coincidence, to say the least. The report of the case of the second daughter is as follows: —

Ophthalmometer. — Astigmatism with the rule, .50 D., axis 90° + or 180° – right eye; astigmatism with the rule, .75 D., 90° + or 180° – left eye.

Test cards and trial lenses. —

R. V. = $\frac{20}{20}$: $\frac{20}{20}$ W. + 1.50 D.

L. V. = $\frac{20}{20}$: $\frac{20}{20}$ W. + 1 D. + .25 D. cyl., 90°.

Reads Jaeger No. 1 from 6 to 20 inches with the left eye, and at the same distance with the right, if the left is covered.

Ophthalmoscope. — H. 2 D. right eye; H. 1.50 D. left eye.

There is a marked inward and upward squint of the right eye (about 20° in and 5° up), and a slight inward squint of the left eye, about 10°. There has been a tenotomy of the left internal rectus some years ago, but the oculist refused to operate on the right eye for fear of overeffect.

Under atropine, this patient accepted + .50 D. more sphere than when without it. I ordered + 1.50 D. right and + 1 D. + .25 D. cyl., 90°, left eye, for constant wear. December 7, I made a complete and thorough tenotomy of the right internal rectus. For the first few days there was a slight divergence. Glasses were left off. After one week the eyes were straight and the patient had single binocular vision. But after two weeks' time the left eye began to turn in. I ordered her to wear the glasses again constantly, and, although the glasses were worn most of the time (the patient taking them off when in the street, against my orders), and atropine (solution 4 gr. to ℥I) was instilled once a day in each eye, it continued to squint. After a month's use the mydriatic was discontinued. The left

eye then turned inward 10°, as it was before the operation on the right, the right now being the eye she fixed with and used. February 3, almost two months after the operation on the right eye, I did a tenotomy of the left internal rectus. There was a decided divergence immediately following, taking 15° prism, base in, to correct. This gradually diminished from day to day, the glass being left off, till at the end of two weeks it was entirely gone and the eye was perfectly straight.

The glasses were now ordered to be worn, but, after one month, they were ordered discontinued permanently, as the right eye had a tendency to diverge if the patient got very tired or excited. I have seen the patient within a few days (nearly five months after the operation), and the eyes are perfectly straight, and binocular single vision is present, both for distance and near. With the stereoscope she can put the bird in the cage, the rider on the horse, etc., with ease.

CASE CIV. *Divergent strabismus right eye; Myopia of large amount each eye; Correction of myopia with glasses; Tenotomy of right external rectus, with advancement of right internal rectus; Cure.* — October 10, 1895, M. C., aged twenty-two years, has been near-sighted since a small child, but the right eye did not turn outward until she was fourteen years old. She wore glasses for a while, but they did not help her much.

Ophthalmometer. — Astigmatism with the rule, .75 D., axis 90° + or 180° − each eye, with slight irregular astigmatism each.

Test cards and trial lenses. —

$$\text{R. V.} = \tfrac{14}{200} : \tfrac{20}{100} \text{ W.} - 12 \text{ D.}$$

$$\text{L. V.} = \tfrac{20}{200} : \tfrac{20}{50} \text{ W.} - 10 \text{ D.}$$

Reads Jaeger No. 4 at 9 inches, with − 8 D. right and − 6 D. left. Single binocular vision is absent.

Ophthalmoscope. — M. 13 D. right eye; 11 D. left eye. There is a posterior staphyloma in each eye, with choroidal

changes in the right. Oblique illumination shows some very fine opacities in the cornea in each eye. Test under atropine resulted in the patient accepting the same glasses as when tested without the mydriatic. Ordered, – 12 D. right and – 10 D. left for distant vision, and – 8 D. right and – 6 D. left for near vision.

October 17, I did a tenotomy of the right external rectus and advancement of the right internal rectus. This operation straightened the eye, and for about four months while under observation it remained straight. Binocular single vision was not secured. This case is a representative one of a typical class of cases, that is, of myopia with divergent strabismus. In such cases, the squint usually develops between the ages of twelve and twenty-five years, and not in early childhood, as does convergent strabismus. Glasses alone, as a rule, do not relieve it, and an operation must be resorted to in order to cure it. Moreover, a simple tenotomy of the antagonist (external rectus), of the weak muscle (internal rectus), or even tenotomy of the associated antagonist (external rectus of the opposite eye), in conjunction, does not, as a rule, relieve it. A tenotomy of the external rectus and an advancement of the internal rectus of the squinting eye is the best procedure to follow, while the external rectus of the non-squinting eye should not, as a rule, be operated upon.

Case CV. *Periodic convergent strabismus at the age of forty-one, following a fixed squint of childhood; Never had glasses or operation; Simple hypermetropia; Squint is non-comitant, though not paralytic; Binocular single vision for distance, but not for near.* — March 1, 1898, Mary H., aged forty-one, came to the clinic of Drs. Lewis and Van Fleet for reading glasses, and was assigned to me to test. She gives a history of squinting at times with the left eye since a child. The left eye, when she was a young girl, turned in all the time, but she "outgrew it," and it rarely turns in now — only when excited or strain-

ing the eyes for close work. The eyes are perfectly straight now: In making the routine test for squint, the following peculiarity in her case was brought out: With the screen test, first covering one eye and then the other, and having the patient look at a pencil held in front of her, it was discovered that when the amblyopic eye — the left, the one that had squinted in childhood — was covered, and the object fixed with the good eye (right), the left eye turned far in toward the nose. But, when the right or good eye was covered with a card, and the object fixed with the left eye, the right did not squint in or out, but remained directed toward the object, as shown both by looking at it back of the card and by it remaining still and fixed on the object when uncovered. If the object was held at twenty feet, no turning of either eye took place when covered or uncovered. Furthermore, with both eyes uncovered, no turning of the left eye took place. It is the only case of the kind that has ever come under my observation, and I called the notice of Dr. Lewis and others to it.

Ophthalmometer. — Astigmatism with the rule, .50 D., axis 90° + or 180° – each eye.

Test cards and trial lenses. —

$$\text{R. V.} = \tfrac{20}{20} : \tfrac{20}{15}\ \text{W.} + 1.50\ \text{D.}$$

$$\text{L. V.} = \tfrac{20}{200} : \tfrac{20}{100}\ \text{W.} + 3\ \ \ \text{D.}$$

Reads Jaeger No. 1 from 8 to 16 inches, with plus .50 D. added to the distance glasses. Ordered + 2 D. right and + 3.50 D. left for reading. The patient has worn these glasses for more than eleven months with entire satisfaction. No distance glasses were given, as the patient did not feel the need of them and would not wear them. I had no desire to have her wear such glasses, since she had gone thus far in life without them; however, she should have had glasses fitted when a child for constant wear. But no operation should have been done, for very likely it would have resulted in a divergent

strabismus, since she "outgrew" or got over the convergent squint without any aid whatever. The case emphasizes the point in a negative way that we should not be in too much of a hurry in operating on young children with convergent squint. Another case in point is the following.

CASE CVI. *Periodic convergent strabismus in childhood recovered from at the age of thirty-one without glasses or operation; Large amount of compound hypermetropic astigmatism in each eye, with marked amblyopia in the left eye; Asthenopia; Relief with glasses.* — February 3, 1899, Miss P. A. B., aged thirty-one years, consulted me because of painful vision. After she reads for a while the eyes get tired, and she has to stop and cover them for a few moments before she can go on again. She has never worn a glass, though when she was young the left eye turned in at times, but by voluntary effort on her part she could prevent the eye from turning. Her parents called her attention to it at first, and she could feel it turn, but by constantly being reminded of it, and with persistent effort, she prevented the eye from turning permanently. After reaching the age of twenty-five she had but little trouble to keep it straight, and now the eye does not turn at all unless under great strain.

Ophthalmometer. — Astigmatism with the rule, 3 D., axis 45° + or 135° – right eye; astigmatism against the rule, 3 D., axis 135° + or 45° – left eye.

Test cards and trial lenses. —

R. V. = $\frac{20}{100}$: $\frac{20}{30}$ W. + 1.50 D. + 3.25 D. cyl., 45°.

L. V. = $\frac{20}{200}$: $\frac{20}{100}$ W. + 3.50 D. + 3.25 D. cyl., 135°.

Reads Jaeger No. 1 from 6 to 16 inches. She has single binocular vision. Ad. 12°, ab. 3°, sur. R. 5°, L. 2°.

Ophthalmoscope. — H. 2.50 D. at 45° and H. 6 D. at 135° right eye; H. 4.50 D. at 135° and H. 8 D. at 45° left eye.

A second test agreed essentially with the first, and the

glasses were ordered. The patient obtained immediate relief from her asthenopia, the tendency of the left eye to turn inward disappeared, and she could read without discomfort. The ophthalmometer in pointing out the slanting axes at which the astigmatic glasses had to be worn in this case was of the greatest assistance, especially in the left or amblyopic eye.

Illustrative Cases of Muscular Insufficiency

In this class of cases, extreme examples of which are fortunately rare, the object of prime importance in all of them is an accurate fitting and adjustment of glasses. This procedure alone, when accurately done, will relieve the great majority of cases of muscular insufficiencies, especially if tonics are given, and an outdoor exercise can be followed for a few hours each day for a month or two.

In the most severe cases, which finally develop into squint, sometimes tenotomy of the muscles has to be done in order to get relief from the deformity, just as in other cases of squint.

Case CVII. *Insufficiency of the internal recti muscles; simple hypermetropia of small amount; Asthenopia; Correction of refractive error; Tonics; Relief.*—February 27, 1897, P. E. R., aged thirty-four years, in good health, has complained for a number of months of a dull and drowsy feeling, also that the eyes were weak and ran water when he used them much. He has a slight conjunctivitis, but not enough to cause his trouble.

Ophthalmometer.—Astigmatism with the rule, .50 D., axis 90° + or 180° − each eye.

Test cards and trial lenses.—

$$R.\ V. = \tfrac{20}{20} - : \tfrac{20}{20}\ W. + .50\ D.$$

$$L.\ V. = \tfrac{20}{20} - : \tfrac{20}{20}\ W. + .50\ D.$$

Reads Jaeger No. 1 from 6 to 18 inches. Ad. 5°, ab. 3°, sur. R. and L. 2°.

Ophthalmoscope.—H. 1 D. in each eye.

An astringent wash was ordered for the conjunctivitis, and strychnine sulphate, gr. $\frac{1}{50}$, as a tonic, three times a day.

Ten days later a second test was made. The ophthalmometer and ophthalmoscope accorded with the first test, and the patient accepted + .50 D. sphere in each eye, as before. Ad. 7°, ab. 3°, sur. R. and L. 2°. Ordered + .50 D. sphere for reading; and the eye wash and strychnine were continued.

Within six weeks' time this patient was entirely free from his asthenopic symptoms, the muscle insufficiency had disappeared, and the patient was comfortable. After two months' treatment I ordered the strychnine stopped, but advised a little outdoor exercise each day. It is now over two years since I first saw him, and he remains free from eye trouble. If he feels "run down" at any time I have him take the tonic of strychnine for four to six weeks, but this has been necessary but twice during the period stated.

Case CVIII. *Marked insufficiency of the internal recti; Simple hypermetropia of moderate amount; Asthenopia; Correction of the refractive error; Tonics; Relief.* — April 17, 1897, Miss L. W. P., aged twenty-one years, in fairly good health, but is hard worked as a stenographer. She has at times had "attacks," in which she would lose consciousness, and during some of these attacks would have involuntary movements of the bowels and bladder, but never bit her tongue. She is rather nervous. She has worn glasses for two and one-half years, but they have not been satisfactory. There is great blurring of images at times, and much pain in the eyes and head after using the eyes for a long while.

Ophthalmometer. — Astigmatism with the rule, .50 D., axis 90° + or 180° − each eye.

Test cards and trial lenses. —

$$\text{R. V.} = \tfrac{20}{20} : \tfrac{20}{15}\ \text{W.} + 1.50\ \text{D.}$$

$$\text{L. V.} = \tfrac{20}{20} : \tfrac{20}{15}\ \text{W.} + 1.25\ \text{D.}$$

Reads Jaeger No. 1 from 6 to 18 inches.

Ophthalmoscope. — H. 2 D. each. Ad. 6°, ab. 7°, sur. R. and L. 2°. Ordered strychnine sulphate, gr. $\frac{1}{60}$, three times a day. Three days later the patient accepted exactly the same glasses as at the first test, and they were ordered. The ad. was 7°, ab. 7°, sur. R. and L. 2°. At the end of one week the patient was perfectly comfortable, and in two weeks the muscle test was as follows: ad. 9°, ab. 7°. sur. R. and L. 2°. In four weeks: ad. 12°, ab. 7°, sur. R. and L. 2°. After two months the strychnine was stopped. These glasses were worn with comfort until December, 1898, almost two years, when she returned, complaining of pain in the left eye. On testing the patient's eyes the following conditions were found: —

Ophthalmometer. — Astigmatism with the rule, .50 D., axis 45° + or 135° − right eye; astigmatism against the rule, .50 D., 135° + or 45° − left eye.

Test cards and trial lenses. —

R. V. = $\frac{20}{20}$ − : $\frac{20}{15}$ W. + 2 D. + .25 D. cyl., 45°.

L. V. = $\frac{20}{20}$ − : $\frac{20}{15}$ W. + 1.75 D. + .25 D. cyl., 135°.

Reads Jaeger No. 1 from 6 to 18 inches.

Ophthalmoscope. — H. 2 D. each. Ad. 7°, ab. 7°, sur. R. and L. 1°.

Three days later a second test was made, the patient accepted the same glasses, and they were ordered. Strychnine sulphate, gr. $\frac{1}{60}$, was ordered to be taken three times a day for a few weeks. It has been four months since these last glasses were ordered; the patient, whom I see from time to time, tells me she is without any pain at all, and can work for long hours.

The patient has had none of her "attacks" since being under my care.

The other interesting feature in this case to me, besides the

insufficiency of the muscles, was the change in the shape of the cornea. When I first saw her, the ophthalmometer showed astigmatism with the rule, .50 D., axis 90° + or 180° –. The patient accepted no cylindrical glass. About two years later the instrument showed astigmatism of .50 D., but the axis was at 45° in the right eye and at 135° in the left. This was a change in the axis of 45° in each eye. Furthermore, the patient accepted + .25 D. cyl., 45° right, and + .25 D. cyl., 135° left, in addition to the spherical glass.

In this case, when I first saw her, the abduction actually exceeded the adduction; yet, with a proper correction of the refractive error, and by the aid of tonics, the patient was not only able to pursue her work with comfort, but was cured of what appeared to be petit mal.

CASE CIX. *Insufficiency of the internal recti muscles; Simple hypermetropic astigmatism; Asthenopia; Correction of the refractive error; Relief.* — October 7, 1893, K. E. H., aged twenty-one years, student, never very strong, has been troubled with his eyes since about twelve years of age. Was fitted to glasses in the Manhattan Eye and Ear Hospital, when seven years of age, and was given + 1 D. sphere combined with 1° prism, base in, for each eye for reading. These glasses helped him very much the first year, but have not been comfortable since then, though they were much better than no glasses. He comes to the clinic again on account of pains in the eyes and headaches.

Ophthalmometer. — Astigmatism with the rule, 1 D., axis 90° + or 180° – right eye; 1.25 D., axis 90° + or 180° – left eye.

Test cards and trial lenses. —

$$\text{R. V.} = \tfrac{20}{15} - : \tfrac{20}{15} + \text{W.} + .50 \text{ D. cyl.}, 90°.$$

$$\text{L. V.} = \tfrac{20}{15} - : \tfrac{20}{15} + \text{W.} + .75 \text{ D. cyl.}, 90°.$$

Reads Jaeger No. 1 from 4 to 20 inches. Ad. 10°, ab. 8°, sur. R. and L. 2°.

Ophthalmoscope. — H. .50 D. at 90° and H. 1 D. at 180° each.

A second test, made very carefully as to the astigmatism, resulted in the patient accepting the same glasses exactly as at the first test. They were ordered. The patient reported at the clinic weekly, for several weeks, as I wished to see if the simple cylinders would relieve him entirely. He said that they gave him relief from the pain in the eyes and his headaches, and were much more comfortable than the spherical glasses and prisms. The internal recti gained in strength also, while the external remained as they were at first.

CASE CX. *Insufficiency of all the recti muscles: Relatively, the external recti were weaker than the others, as an homonymous diplopia was present at times; Compound hypermetropic astigmatism; Correction of refractive error; Tonics; Relief.* — November 20, 1894, Sadie G., aged fourteen years, in good health, came to the clinic of Drs. Lewis and Van Fleet, and was assigned to me for examination. She complains of seeing double at times, but otherwise has had very little trouble with her eyes. For the last few weeks the lids have been somewhat inflamed, and stick together in the morning.

Ophthalmometer. — Astigmatism with the rule, 1 D., axis 90° + or 180° − each eye.

Test cards and trial lenses. —

$$\text{R. V.} = \tfrac{20}{40} : \tfrac{20}{20} \text{ W.} + .50 \text{ D. cyl., } 90°.$$

$$\text{L. V.} = \tfrac{20}{30} : \tfrac{20}{15} \text{ W.} + .50 \text{ D. cyl., } 90°.$$

Reads Jaeger No. 1 from 5 to 15 inches. A 1° prism gives diplopia in every direction, and over whatever muscle the apex is placed. The fact, however, that the patient has occasional

homonymous diplopia, especially when looking at near objects, would indicate a relative weakness of the external recti muscles.

Ophthalmoscope. — H. .50 D. at 90° and H. 1 D. at 180° in each eye.

A mild astringent wash was ordered for the lids and strychnine sulphate, gr. $\frac{1}{60}$, three times a day, as a tonic.

One week later, a second test was made. The ophthalmometer and ophthalmoscope gave the same results as at the first test, and the patient again accepted simple cylindrical glasses, which were ordered.

The muscles were in exactly the same condition as the week previous. The patient was instructed to wear the glasses constantly, to continue the tonic of strychnine, to take some outdoor exercise, and to report in one month. At the end of a month the patient had no diplopia, eyes comfortable, and she was feeling much better in every way. Ad. 4°, ab. 1°, sur. R. and L. 1°. The patient was ordered to report if the eyes troubled her again, but has not been seen since then.

CASE CXI. *Insufficiency of all of the recti muscles; Troublesome homonymous diplopia; Compound hypermetropic astigmatism; Asthenopia; Dizziness; Correction of refractive error; Tonic given, and less work ordered; Relief.* — December 26, 1893, Miss B. C., aged thirteen years, came to the clinic of Drs. Lewis and Van Fleet, complaining of dizziness and of seeing double at times. The patient has always enjoyed good health, and her father and mother are living and in good health. She has one brother and three sisters, all younger than herself, and with no eye troubles of any kind. The patient is very studious, goes to school during the day and studies till eleven o'clock at night, besides doing outside reading.

Ophthalmometer. — Astigmatism with the rule, 2 D., axis 90° + or 180° − right eye; 2.75 D., axis 90° + or 180° − left eye.

Test cards and trial lenses. —

R. V. = $\frac{20}{70}$: $\frac{20}{30}$ W. + 1.25 D. cyl., 90°.

L. V. = $\frac{20}{100}$: $\frac{20}{30}$ W. + 2 D. cyl., 90°.

Reads Jaeger No. 1 from 6 to 14 inches. A 1° prism gives diplopia in all directions, that is, when the apex is placed over any one of the recti muscles it causes diplopia.

The diplopia that the patient complains of, and which can be produced at will by putting a red glass in front of one eye, is homonymous most of the time, but occasionally is crossed, especially when the patient first looks at near objects.

Ophthalmoscope. — H. 1 D. at 90° and H. 3 D. at 180° right eye; H. 2 D. at 90° and H. 4 D. at 180° left eye.

Ordered strychnine sulphate, gr. $\frac{1}{60}$, taken three times a day, and to do less work with the eyes; also an hour's walk each day. Four days later a second test was made.

Ophthalmometer. — Astigmatism with the rule, 1.75 D., axis 90° + or 180 °− right eye; 2.50 D., axis 90° + or 180° − left eye.

Test cards and trial lenses. —

R. V. = $\frac{20}{50}$: $\frac{20}{20}$ W. + 75 D. + 1.25 D. cyl., 90°.

L. V. = $\frac{20}{50}$: $\frac{20}{20}$ W. + 75 D. + 2 D. cyl., 90°.

Reads Jaeger No. 1 from 6 to 15 inches. The ophthalmoscope showed the same condition as at the first test. A third test, two days later, resulted in the patient accepting the same glass as that accepted on the second, and the glasses were ordered for constant wear; the tonic was continued, and the patient admonished not to use the eyes to the point of abuse as she had been doing.

An immediate effect of the glasses was the relief of the diplopia and dizziness. If she took the glasses off, diplopia would manifest itself, but while she kept them on she had relief.

These two cases just reported show that muscular insufficiency of marked degree, and even when attended with occasional diplopia, may be relieved by glasses and tonics, without operative interference. Sometimes, however, it will not yield to this simple procedure, and an operation has to be resorted to, as shown by the following case.

CASE CXII. *Insufficiency of the internal recti; Simple hypermetropic astigmatism; Occasional crossed diplopia; Dizziness; Marked asthenopia; Correction of refractive error and tonics without relief; Prisms added to glasses without relief, but with the development of divergent squint; Operation; Relief.* — Miss Celia L., aged twenty years, in good health, consulted me first on September 12, 1893, on account of pains in the eyes, headaches, dizziness, and because she saw double occasionally. She was fitted with glasses two years ago, which were comfortable until she began to sew on fine work about two months ago.

Ophthalmometer. — Astigmatism with the rule, 2.75 D., axis 120° + or 30° − right eye; 2.75 D., axis 90° + or 180° − left eye.

Test cards and trial lenses. —

$$\text{R. V.} = \tfrac{20}{70} + : \tfrac{20}{30} + \text{W.} + 2.25 \text{ D. cyl., } 120°.$$

$$\text{L. V.} = \tfrac{20}{50} - : \tfrac{20}{30} - \text{W.} + 2.25 \text{ D. cyl., } 90°.$$

Reads Jaeger No. 1 from 6 to 18 inches. Ad. 5°, ab. 7°, sur. R. and L. 1°.

Ophthalmoscope. — Em. at 120° and H. 2 D. at 30° right eye; Em. at 90° and H. 2 D. at 180° left eye.

The patient has been wearing for a year + 2 D. cyl., 120°, right, and + 2 D. cyl., 80°, left; and these glasses give her about as good vision as the glasses she now accepts. Ordered tonic of strychnine, and a mild astringent wash, for a slight conjunctivitis that is present.

Three weeks later the patient returned, not improved, but

worse as regards the insufficiency. The glasses could not be improved upon: ad. .1°, ab. 9°, sur. R. and L. 2°. She has great pain in using the eyes, and the diplopia is more troublesome than ever. With a red glass in front of one eye, the diplopia is constant, vertical, and crossed. Prism 1°, base down, and prism 5°, base inward, in front of left eye, corrects same. These prisms, divided between the two eyes, were added to her glasses, and for four months she was very comfortable; but, on February 14, 1894, she returned, complaining of her old symptoms, especially of the diplopia, which was constant. A divergent strabismus of between 5° and 10° was present in the right eye.

An operation was advised and performed — a complete tenotomy of the right external rectus muscle. A very small opening was made in the conjunctiva, and then in the capsule of Tenon, being careful not to dissect up the capsule to any great extent, but just enough to pick up the tendon of the muscle, which was divided completely.

At first there was over-correction, the eye turning inward too far by 15°, as shown by the prism which it took to correct a homonymous diplopia. Ordered to wear her glasses without prisms. In one month's time the eyes were perfectly straight, ad. 15°, ab. 6°, sur. R. and L. 2°, single binocular vision. The patient was entirely comfortable, and able to pursue her vocation as a seamstress.

The angle *alpha* in this case was positive, but very narrow, 2°; and this may, in a measure, account for the insufficiency of the internal recti muscles, developing into a divergent strabismus.

This patient is still under observation, and she is comfortable. The following case is similar to the present one, but no prism was tried before the operation was done.

CASE CXIII. *Insufficiency of the internal recti muscles; Occasional diplopia for the near point; Hypermetropia of small*

amount, with slight astigmatism in the left eye; Marked asthenopia; Glasses, tonics, prism exercises, open-air exercises, and rest, all fail to relieve; Tenotomy of the right external rectus, followed in two and one-half years with tenotomy of the left external rectus, effect a cure. — June 1, 1896, C. H. M., aged seventeen years, in only fairly good health; his vitality is much reduced on account of long hours of study and sexual excesses. He has passed through many hands, — sixteen in all, — has worn glasses and taken tonics, but without relief from headaches and pains in the eyes, of which he complains. The headaches are present even in the morning, and are intensified by using the eyes. Print doubles after using the eyes for a little while. If he cannot get relief, he says he must give up his studies. He comes from a healthy family, and none of them, except himself, are troubled with their eyes.

Ophthalmometer. — Astigmatism with the rule, .50 D., axis 90° + or 180° – each eye.

Test cards and trial lenses. —

$$\text{R. V.} = \tfrac{20}{20} : \tfrac{20}{15} - \text{W.} + .50\ \text{D.}$$
$$\text{L. V.} = \tfrac{20}{20} : \tfrac{20}{15} - \text{W.} + .25\ \text{D. cyl., } 90°.$$

Reads Jaeger No. 1 from 6 to 15 inches. Ad. 10°, ab. 9°, sur. R. and L. 3°.

Ophthalmoscope. — H. 1.50 D. each eye.

Ordered strychnine sulphate, gr. $\frac{1}{30}$, three times a day, the patient to study less, to desist from his excesses, and to take more outdoor exercise. He has been riding the bicycle considerably already.

Three days later, a second test was made, and but little change in the condition of the eyes was found. Ordered: + .50 D. right, and + .25 D. cyl., 90°, left, to be worn constantly, and the other treatment continued. Ten days later, the eyes not improving, the strychnine was increased to gr. $\frac{1}{15}$, three times a day, the patient being cautioned as to the physio-

logical effect of the strychnine. Prism exercises were ordered in addition to other treatment, although I have little faith in such exercises, and would not now advise them.

Six weeks later, the patient getting no better, but worse, — ad. 9°, ab. 10°, sur. R. and L. 3°, — I advised tenotomy of the right external rectus, and this was performed August 14. Homonymous diplopia immediately following, from over-correction, required prism 10°, base out, to correct. Eleven days later, the diplopia disappeared, ad. 16°, ab. 4°, sur. R. and L. 2°. September 21, ad. 14°, ab. 6°, sur. R. and L. 2°, eyes perfectly comfortable, and he resumed his studies.

February 16, 1897. He has trouble again with his eyes, from too close application to studies and from sexual excesses. Tonics and rest relieved him.

January 4, 1898. Patient returns, complaining that he does not feel well, has had some trouble with his heart, headaches, general lassitude, and eyes suffer, with general depressed condition. He continues to dissipate from time to time. His old glasses cannot be improved upon. The vision in each eye $= \frac{20}{20}$; ad. 10°, ab. 8°, sur. R. and L. 2°. I told the patient I could do no more for him unless he obeyed instructions and stopped dissipating. He went to another oculist, who put him under a mydriatic, and gave him + 1.50 D. each eye, full correction. These glasses did not give him relief. The adduction was already too weak, and to put full correction of his hypermetropia on him simply made it weaker; and when he came to me again, on December 20, 1898, he was complaining of diplopia, much headache, and pains in the eyes. Ad. 8°, ab. 9°, sur. R. and L. 2°. Advised and performed a tenotomy of the left external rectus. A decided convergence followed, requiring prism 20°, base out, to correct it. Glasses were left off. The convergence gradually diminished, as it had after the operation on the right eye; and, by January 25, 1899, — about five weeks, — parallelism existed; ad. 20, ab. 2°, sur. R.

and L. 2°. February 10, ad. 16°, ab. 5°, sur. R. and L. 2°. The patient is perfectly comfortable, and able to use the first glasses given him.

It has been five months since the last operation ; the patient has no asthenopia, is comfortable, and in school.

CASE CXIV. *Insufficiency of the internal recti; Asthenopia; Photophobia; Neuralgia; Emmetropia; Reading glasses ordered; Tonics; Improvement in the eyes, but not entire relief from asthenopic symptoms.* — March 25, 1898, Miss F. M., aged forty-three years, in delicate health, complains that her eyes have troubled her for a year. She thinks it has something to do with an ovarian neuralgia (right side) from which she has suffered for the last year. The pain begins in the eyes first, as a rule, but often it is just the reverse. She has severe headaches, especially in the back part of her head.

For the last three weeks she has suffered greatly from severe pain in the eyes and from photophobia, and has been compelled to wear blue glasses to keep the light out of her eyes.

Ophthalmometer. — Astigmatism with the rule, .50 D., axis 90° + or 180° − each eye.

Test cards and trial lenses. —

R. V. = $\frac{20}{20}$ + : not improved.

L. V. = $\frac{20}{20}$ + : not improved.

Reads Jaeger No. 1 from 8 to 20 inches, with + .50 D.

Ad. 10°, ab. 8°, sur. R. and L. 2°.

Ophthalmoscope. — Emmetropia each. Some congestion of the fundus in each eye, but no lesion.

Ordered + .50 D. for each eye for reading. Under a tonic of strychnine and arsenic, general hygiene and rest, she was much improved in general health ; and her ovarian neuralgia and also the asthenopia and photophobia were helped, but not entirely relieved. However, she would have periods when all

of her old symptoms would reappear. Her adduction was increased to 14°, while ab. and sur. remained as before.

In such a case as this it would have been futile to cut the ocular muscles, for the asthenopia and ovarian trouble were likely both due to a common cause. At any rate, when she was feeling well, generally, the eyes gave her little or no trouble, indicating clearly that the eye trouble was not local, but due to a general debility.

CASE CXV. *Insufficiency of the internal recti; Small amount of hypermetropia; Presbyopia; Asthenopia; Correction for near work; Tonics; Exercise; Relief.* — December 29, 1896, C. H., Esq., aged fifty years, in good health, but uses his eyes excessively. He complains of pain in the eyes and of redness of the lids after using the eyes in the evening. He has had rheumatism in mild attacks for the last few years.

Ophthalmometer. — Astigmatism with the rule, .50 D., axis 90° + or 180° − both.

Test cards and trial lenses. —

$$\text{R. V.} = \tfrac{20}{20} : \tfrac{20}{20} + \text{W.} + .50\ \text{D.}$$

$$\text{L. V.} = \tfrac{20}{20} : \tfrac{20}{20} + \text{W.} + .50\ \text{D.}$$

Reads Jaeger No. 1 from 8 to 24 inches, with + 3 D. sphere. Ad. 10°, ab. 8°, sur. R. and L. 2°.

Ophthalmoscope. — H. .50 D. each eye.

One day later, a second test was made, and the patient accepted the same glasses as at the first test. Ordered + 3 D. each eye for reading. Also ordered a tonic of strychnine and open-air exercise. After three months' treatment, adduction 15°, ab. 7°, sur. R. and L. 3°. The patient is entirely comfortable and able to use his eyes for long hours. The strychnine was stopped. I saw this patient a year later, and again two years later. He accepted no increase in presbyopic glass; ad. 14°, ab. 6°, sur. R. and L. 2°; was still entirely comfortable, but as he was passing through the city, stopped to let me see him.

CASE CXVI. *Insufficiency of the internal recti; Mixed astigmatism in one eye, and compound hypermetropic astigmatism in the other; Occasional diplopia at the near point; Severe headaches; Has had a number of graduated tenotomies; Correction of refractive error; Tonics; Relief.* — January 9, 1894, W. J. C., aged twenty years, in fairly good health, a close student, consulted me on account of severe headaches, and because he saw double for near work after using the eyes for any considerable time. He is one of the unfortunates who has been subjected to several, he does not know just how many, graduated tenotomies. From moderate headaches and no diplopia before the operations, he now has very severe headaches and frequently diplopia for the near point.

Ophthalmometer. — Astigmatism with the rule, .50 D., axis 105° + or 15° − right eye; with the rule, 2.25 D., axis 105° + or 15° − left eye.

Test cards and trial lenses. —

R. V. = $\frac{20}{20}$: $\frac{20}{15}$ W. + .25 D. cyl., 105°.

L. V. = $\frac{20}{30}$: $\frac{20}{20}$ W. + 1.25 D. cyl., 105° − .75 D. cyl., 15°.

Reads Jaeger No. 1 from 4 to 15 inches. Ad. 2°, ab. 6°, sur. R. and L. 1°.

Ophthalmoscope. — H. .50 D. right eye; H. 1 D. at 15° and M. 1 D. at 105° left eye.

Ordered strychnine sulphate in increasing doses, and rest and exercise for a few days.

Second test: the ophthalmometer gave the same readings as at the first test.

Test cards and trial lenses. —

R. V. = $\frac{20}{20}$: $\frac{20}{15}$ W. + .25 D. cyl., 105°.

L. V. = $\frac{20}{30}$: $\frac{20}{20}$ W. + 1 D. cyl., 105° − .50 D. cyl., 15°.

Reads Jaeger No. 1 from 4 to 17 inches. Ad. 4°, ab. 6°, sur. R. and L. 2°.

On a third test, the patient accepted exactly the same glasses as at the second, and they were ordered. The strychnine, gr. $\frac{1}{30}$, was given three times a day, and the patient directed to take some outdoor exercise each day. Within three weeks' time this patient's adduction exceeded his abduction (ad. 7°, ab. 6°), his headaches and diplopia were gone, and he was able to use his eyes with comfort. The strychnine was continued for two months, when adduction was 10°, ab. 6°, and sur. R. and L. 2°.

May 2, 1896, over two years after I first saw him, the patient returned with headaches and pains in the eyes. On inquiring, I found that he had broken the right glass, and had a new one put in without an order. On examination, I found the optician had put a cylinder in the right eye, axis at 75°, instead of 105°, as it should have been. The refraction had changed slightly in the left eye, the patient now accepting + .75 D. cyl., 105° – 1 D. cyl., 15°. Ad. 7°, ab. 7°, sur. R. and L. 2°.

I again placed the patient on a tonic of strychnine, gr. $\frac{1}{60}$, three times a day, for two months. I have heard from this gentleman, from time to time, for two years after this last examination, and though at times, when very hard worked or not feeling well, he has some pain in the eyes, he has no diplopia, and, as a rule, is comfortable, and can pursue his calling as a minister.

Case CXVII. *Insufficiency of the internal recti; Occasional diplopia; Asthenopia; Hypermetropia and Presbyopia; Reading glasses; Tonics; Relief.* — November 26, 1896, Dr. D. L. H., aged forty-three years, in good health, has worn glasses for the last eighteen years. He complains of late that when he uses the eyes for any considerable time he gets pains in the back of the head and in the eyes.

Ophthalmometer. — Astigmatism with the rule, .50 D., 90° + 180° – right eye; with the rule, .25 D., 90° + 180° – left eye.

Test cards and trial lenses. —

$$R. V. = \tfrac{20}{20} : \tfrac{20}{15} \text{ W.} + 75 \text{ D.}$$

$$L. V. = \tfrac{20}{20} : \tfrac{20}{15} \text{ W.} + 75 \text{ D.}$$

Reads Jaeger No. 1 from 8 to 16 inches, with + 1.50 D. sphere in each. Ad. 10°, ab. 9°, sur. R. and L. 3°. If the patient does not fix his attention closely on objects, one eye will at times diverge; but by effort he can overcome this. Ordered + 1.50 D. sphere, each eye, for reading, but discontinued his distance glasses. Strychnine was given in increasing doses till physiological effect was obtained. The patient got almost immediate relief. I wrote to the doctor two years later for a report of his case, and his reply is here given.

"Dear Doctor Davis, —

"Yours, relative to the condition of my eyes, is received. My eyes remained about the same for another year, when, on account of increased irritability, I increased strength of glass from 1.50 D. to 1.75 D., which gives me absolute relief to the present time.

"Thanking you, etc.,

"D. L. H."

The muscular insufficiency in this case was so marked that a periodical squint was present; yet, with the correct glass for reading and tonics, he was cured.

Case CXVIII. *Insufficiency of the internal recti made worse by wearing strong prisms, bases in; Incapacitated for work on account of the great pain in the eyes and head; Compound myopic astigmatism; Mild trachoma; By taking off the prisms and giving the proper glasses, the patient got entire relief, and was able to resume his professional calling, that of a lawyer.* — October 1, 1898, H. A. T., Esq., aged thirty-six, in good health, except for his eyes, which have given him trouble for the last eighteen years. Has had a more or less severe inflammation of the lids for that time. His chief trouble, however, has been

from a weakness of the eyes and inability to use them for any considerable length of time without great pain in them and severe headaches. Has consulted a number of oculists, and has tried many kinds of glasses, without much relief. In fact, he had to give up his profession on account of his eyes, because, after reading for a short time, the pain in his eyes would become unbearable.

He has worn for the last two years – 1.50 D. – 1.50 D. cyl., 170° right, and – 2 D. – 1 D. cyl., 180° left, combined with 5° prisms, bases in. These glasses gave him partial relief at first, but for the last year he thinks the eyes have been made worse. But as no other glasses — of which he had many pairs, plus, minus, with prisms and without — had given him any relief, he held to these until forced to try something else. I treated the eyelids for three months before testing for glasses, as I wished to eliminate that factor of the trouble. January 3, 1899, I made the first test.

Ophthalmometer. — Astigmatism with the rule, 2.50 D., axis 80° + 170° – right eye; with the rule, 2 D., axis 100° + or 10° – left eye.

R. V. = $\frac{18}{200}$: $\frac{20}{15}$ – W. – 1.25 D. – 2 D. cyl., 170°.

L. V. = $\frac{12}{200}$: $\frac{20}{15}$ – W. – 1.25 D. – 2 D. cyl., 10°.

Reads Jaeger No. 1 from 7 to 24 inches. Ad. 11°, ab. 13°, sur. R. 5°, L. 4°. Single binocular vision with effort.

Ophthalmoscope. — M. 3 D. at 75° and M. 1 D. at 165° right eye; M. 3 D. at 105° and 1.50 D. at 15° left eye.

Ordered prism exercises.

January 9. Ophthalmometer and ophthalmoscope gave the same readings as at the first test.

R. V. = $\frac{18}{200}$: $\frac{20}{15}$ – W. – 1 D. – 2.25 D. cyl., 170°.

L. V. = $\frac{12}{200}$: $\frac{20}{15}$ – W. – 1.25 D. – 1.50 D. cyl., 10°.

Ad. 17°, ab. 10°, sur. R. 4°, and L 3°.

January 18. A third test corresponded with the second.

Since this patient had had so many glasses, and all unsatisfactory, I put him under the influence of a mydriatic (scopolamine), and on January 27, tested him under it, as follows: —

Ophthalmometer. — Astigmatism with the rule, 2.50 D., axis 80° + or 170° − right; 1.50 D., axis 100° + or 10° − left eye.

Test cards and trial lenses. —

R. V. = $\frac{15}{200}$: $\frac{20}{20}$ + W. − .75 D. − 2 D. cyl., 170°.

L. V. = $\frac{70}{200}$: $\frac{20}{20}$ + W. − 1.25 D. − 1.25 D. cyl., 10°.

Ad. 10°, ab. 10°, sur. R. 6°, L. 4°.

Ophthalmoscope. — M. 3 D. at 75° and M. 1 D. at 165° right eye; M. 3 D. at 105° and M. 1.50 D. 15° left eye.

The retinoscope confirmed the ophthalmoscopic and subjective tests. The angle *alpha* was 3° in each eye. Ordered the glasses that were accepted under the mydriatic.

February 3. Patient reports entire relief from all asthenopic symptoms, is able to read for long hours without discomfort, and is altogether happy. There is none of the drawing sensation in the eye as with the old glasses, and the weight of the glass itself is much less than the old heavy prismatic glasses.

The old mistakes of over-correcting the spherical part of the error of refraction, and under-correcting the cylindrical part, had been committed in this case, and besides these errors, the burdensome prisms of 5°, bases in, were added to the glasses. These prisms were gradually forcing the eye into a divergent squint. When I first saw the patient he had an adduction of only 11° and an abduction of 13°, and the patient was under a constant strain in order to have single binocular vision.

After two weeks' wearing of the glasses without prisms, the patient had ad. 18°, ab. 9°, sur. R. 4°, L 3°. He has been under observation for three months since the glasses were pre-

scribed, expresses himself as being entirely comfortable, and able to work with satisfaction for the first time in many years.

While on this question of prisms, I may say that within a month I have removed a pair of prisms from a patient with a well-marked convergent strabismus, in which none of the refractive error had been corrected, the patient wearing a simple prism 3°, base out, in front of each eye. No binocular single vision was present, and, of course, the prisms were worse than useless. Except in cases of paralytic squint, where they are to be recommended for temporary use until the patient has recovered under treatment, or by operation, prisms should not be given in strabismus cases.

CHAPTER X

ASTIGMATISM AFTER CATARACT EXTRACTION — TORIC LENSES — PERISCOPIC LENSES — DECENTERING OF LENSES — ILLUSTRATIVE CASES

As would be supposed, the aphakial or lensless eye, where the corneal astigmatism only has to be considered, is the ideal eye for the use of the ophthalmometer. Nevertheless, the nodal point is moved forward by the removal of the crystalline lens, and hence the cylinder being combined, almost without exception, with a strong spherical glass, which must be worn one-half inch in front of the eye, the strength of the glass necessary for the correction of the astigmatism is rarely ever as great as that indicated by the ophthalmometer, even though the astigmatism is against the rule. The same law for reduction in strength holds in regard to prescribing spherical glasses after cataract extraction. For example, say the amount of hypermetropia in an eye after cataract extraction is 11 D. Now, since there is no crystalline lens in such an eye, it would naturally seem that it would require a + 11 D. ($3\frac{1}{2}$ inch) lens to correct this error, and, as a matter of fact, it would, could the glass be worn in contact with the cornea. But since the ordinary wearing distance of a glass from the eye is 12 to 14 mm., or about one-half inch, this moving forward of one-half inch perceptibly increases the strength of strong convex glasses, and, therefore, a reduction in strength must be made. In the present supposed example of 11 D. hypermetropia, instead of there being required a + 11 D. to correct it, a much weaker glass, when placed at the usual one-half inch wearing distance in front of the eye, will accomplish what is required. To be exact, it would require a glass of only $3\frac{1}{2}$ in. + $\frac{1}{2}$ in. (the $\frac{1}{2}$ in.

being the distance in front of the eye that the glass is worn), which equals a four-inch focus glass; and a four-inch focus glass equals 10 D. By which it is seen that one whole diopter is deducted from the glass.

This increase of the power of convex glasses, on account of this one-half inch (projection from the cornea) in front of the eyes, obtains in all other eyes, as well as in aphakia, but the glasses, as a rule, in other than aphakial eyes, are so weak that the slight displacement of one-half inch does not make a great difference in their strength. There are exceptional cases where it does, but they are rare. In cataract cases, however, the glasses must be very strong, except when the eye has been strongly myopic before operation, and a slight change in the position of the glass in front of the cornea makes a great difference in the power of the glass, as shown above. To give another example, say the patient was hypermetropic 5 D. before the operation, and after the operation that he has a hypermetropia of 16 D. It is evident that if a plus glass of 16 D. ($2\frac{1}{2}$ in. focus) could be worn in contact with the cornea it would correct the 16 D. of hypermetropia; but, as it must be worn one-half inch in front of the eye, it must be reduced in strength. That is, it would require a glass of $2\frac{1}{2} + \frac{1}{2} = 3$ in. focus, which equals only 13 D., a decrease in strength of three diopters.

The discrepancy in the reading of the ophthalmometer and the cylindrical glass accepted by the patient after cataract extraction is not because of an error in the reading of the instrument, but is to be ascribed chiefly to the great reduction in strength that has to be made in strong cylinders on account of the one-half inch distance at which they must be worn in front of the eye, especially so when combined with strong spherical glasses. For example, if we have an astigmatism of 3 D. against the rule, 180° +, and hypermetropia 10 D.; the power of the glass to correct in the vertical meridian would be 13 D., and the horizontal meridian 10 D., if they could be worn in con-

tact with the eye. But they are one-half inch in front of the eye. 13 D. = 3 in. focus, + $\frac{1}{2}$ in. (in front of the eye) = $3\frac{1}{2}$ in. focus = 11 D. for the vertical meridian. For the horizontal meridian, 10 D. = 4 in., + $\frac{1}{2}$ in. = $4\frac{1}{2}$ in. = 9 D. The difference between 11 D. and 9 D., the glasses which respectively it requires to correct the vertical and horizontal meridians, on account of their position in front of the eye, is only 2 D.; and, therefore, it would take but 2 D. cyl. to correct the 3 D. of corneal astigmatism. Again, take 6 D. of astigmatism, 180° +, with 10 D. of H. The vertical meridian would require 16 D. ($2\frac{1}{2}$ in.) to correct it, if worn in contact with the eye; $2\frac{1}{2}$ in. + $\frac{1}{2}$ in. = 3 in. = 13 D., which glass it really takes. The horizontal meridian would take 10 D. (4 in.); 4 + $\frac{1}{2}$ = $4\frac{1}{2}$ in. = 9 D. Now, 13 D. − 9 D. = 4 D., the amount of cylinder, axis 180°, it takes to correct the 6 D. of corneal astigmatism.

Carl Weiland, in writing on the subject, has this to say: —

"Cases of aphakia are, therefore, the ideal field for keratometry, but owing to the high spheres usually necessary, there is a great difference between the correcting cylinder at 14 mm. from the eye and that in contact with the cornea, which latter, as we know, is given by Javal's instrument. The following table will show this at a glance, which is given for + 10 D. for far, and + 14 D. for reading.

Table

A	Δ	Full Correction	A	Δ	Full Correction
+ 1	+ 10	+ 10 − .75 cyl.	+ 1	+ 14	+ 14 − .66 cyl.
− 1	+ 10	+ 10 + .73 cyl.	− 1	+ 14	+ 14 + .65 cyl.
− 2	+ 10	+ 10 + 1.45 cyl.	− 2	+ 14	+ 14 + 1.25 cyl.
+ 2	+ 10	+ 10 − 1.50 cyl.	+ 2	+ 14	+ 14 − 1.3 cyl.
− 3	+ 10	+ 10 + 2.1 cyl.	− 3	+ 14	+ 14 + 1.8 cyl.
− 4	+ 10	+ 10 + 2.8 cyl.	− 4	+ 14	+ 14 + 2.5 cyl.
− 5	+ 10	+ 10 + 3.50 cyl.	− 5	+ 14	+ 14 + 3.18 cyl.
− 6	+ 10	+ 10 + 4.1 cyl.	− 6	+ 14	+ 14 + 3.66 cyl.

"This shows conclusively the necessity of correcting in aphakia the keratomically determined cylinder for its position and for the coexisting axial condition, for even with a + 1 D. it amounts to .25 D. and more, while for an astigmatism of 6 D. against the rule, it amounts to almost 2.50 D. At the same time, we observe that in the same individual the cylinder may have to be reduced perceptibly for reading. We also find that the numbers obtained by the keratometer are *always* too high, no matter whether the astigmatism is with or against the rule." [1]

Theoretically, Weiland's position is correct, but in practice, I have, more than once, seen the patient accept exactly what the instrument indicated, and even more. As a general thing, though, after cataract extraction, the patient will not accept as much cylindrical correction as indicated by the instrument.

There is another feature of error in the ophthalmometer itself, in high degrees of astigmatism, 6 D. and over, — *spherical aberration.*

Thomas Reid, of Glasgow, in an article on the "Scope and Limits of Ophthalmometry," [2] calls attention to this point. He says: "With Javal's instrument with an image of 3 mm., and with the portable ophthalmometer (Reid's) with an image of 2 mm., it is clear that from the spherical aberration the absolute size of the radius cannot be determined without reduction, as Leroy has done. Hence the necessity in these instruments of being adjusted to a spherical surface of known curvature, which at most expresses approximately the average curvature of the cornea. The results obtained by these instruments thus adjusted, although not theoretically perfect, will give the relative difference in degrees of corneal astigmatism

[1] "History and Principles of Keratometry," Knapp's *Archives of Ophthalmology,* January, 1893.

[2] *Annals of Ophthalmology*, July, 1897, p. 456.

not greater than 5 D. with sufficient accuracy for practical purposes."

In regard to the limit of the measuring power of the Javal-Schiötz ophthalmometer, especially its capacity to determine the relative difference of the refractive power of the two principal meridians, even in very high degrees of astigmatism, I may say the same restriction does not hold in the Javal-Schiötz instrument as in Reid's, and for the following reason: In both instruments the size of the image remains constant (3 mm. in Javal's, and 2 mm. in Reid's), but the size of the object varies.

In Reid's instrument,[1] the object measured is an iris diaphragm, which can be made to vary in size. Now, "in this instrument, if we take the extremes of the index, $0 = 12$ mm. and $0 = 16$ mm., we find the corresponding diopters are 38.9 D. and 51.84 D." The difference between these two amounts, $51.84 - 38.9 = 12.94$, or about 13 D., the amount of the astigmatism (with the prism giving an image of 2 mm.) the instrument is capable of measuring.

In Javal's instrument, the object is the distance between the inner edges of the mires. When both of these mires move at once, as in the instrument with the double movable mires, the size of the object can be made to change from 10 cm. (100 mm.) to 40 cm. (400 mm.), the corresponding diopters to these numbers equal 20 D. and 80 D., respectively; and the difference between 80 D. and 20 D. equals 60 D., the amount of astigmatism the instrument is capable of measuring. Of course it could show such a great difference in only a relative way, because the spherical aberration would be so great in such a case that the measurement would not be accurate, but only approximate.

But it is the difference in the limit of the measuring power of the two instruments I wish to show. One has the capacity

[1] See description of Reid's Ophthalmometer in Appendix.

to measure 13 D. of astigmatism, while the other has the capacity to measure 60 D. While no such amount as 60 D. of astigmatism has ever been met with in practice, yet so large amount as 28 D. of astigmatism (and not after cataract extraction) has been seen and measured with the Javal ophthalmometer, the patient accepting exactly the cylindrical glass indicated by the instrument.[1]

Both the Javal and the Reid instruments may have the limit of their measuring power increased by taking out the usual birefractive prisms that come with them, and substituting prisms that give an image of only 1 to 1½ mm. in diameter. But ordinarily this is not required, and, moreover, it is not convenient. Except for scientific investigations, these extra prisms are not necessary, because both instruments are capable of measuring any case of astigmatism ordinarily met with; for, except in cases of conical cornea and cases after cataract extraction, we rarely encounter an astigmatism of more than 5 or 6 D. As far as the cases of conical cornea are concerned, fortunately they are rare, even they can be measured fairly accurately with. the ophthalmometer.

As for the astigmatism we meet with after cataract extraction, while it is very great in some cases shortly after the extraction (two to three weeks), amounting in rare instances to as much as 22 D., this, as a rule, rapidly diminishes, till within six weeks to two months it rarely amounts to more than 5 or 6 D., although in one case I have seen 12 D. of astigmatism remain permanently after extraction. So here again the ophthalmometer is within its range of practical and accurate work.

The latest investigations as to the amount of the astigmatism after cataract extraction, both immediately (two weeks) after and several months later, are those of E. O. Pfingst, of Louisville, in Knapp's *Archives of Ophthalmology*.[2] In a series

[1] Dodd's case, cited in full farther on in this chapter.

[2] Bd. Vol. XXV, 1896, pp. 333-340.

of fifty cases, he found that the astigmatism, two weeks after operation, ranged from 1.75 D. with the rule to 22 D. against the rule; that this rapidly diminished in amount for the next two to four weeks, then gradually diminished in amount for six months, after which, in the few cases which he had the opportunity of examining, he found no further change in the astigmatism.

My own experience is similar to that of Pfingst and others who have made investigations in this class of cases. In private practice, and especially at the Manhattan Eye and Ear Hospital, where I was Interne for two years, I have made many observations with the ophthalmometer after cataract extractions. In some cases I have made the examination as early as the tenth day after the extraction. The first examination usually showed a considerable amount of astigmatism against the rule (4 to 8 D.), while one showed as much as 22 D. In a few cases, the astigmatism was with the rule, and amounted to as much as 4.50 D. in one case.

In all of the cases that I have observed, the astigmatism has rapidly diminished in amount, till in no case, with two exceptions, six months after operation, did it amount to as much as 8 D., even where the astigmatism had been as much as 22 D. the first two weeks after operation. Furthermore, in some cases of astigmatism against the rule of as much as 4 D. to 6 D. in amount, it vanished entirely; and, in some cases, an astigmatism of as much as 2 D. to 4 D. against the rule changed to astigmatism with the rule. One case of 4.50 D. astigmatism with the rule diminished gradually to nothing, then an astigmatism of 1.50 D. against the rule developed.

Complicated cases of cataract extraction are the ones that give rise to the largest amounts of astigmatism, incarceration of the iris in the whole length of the wound exerting the greatest influence on the shape of the cornea, perhaps. Pfingst's

case of 22 D. had this complication. The case of 22 D. observed by me occurred in a woman whom I operated on at the hospital, who fell over backward from a stool at the end of the first week after the operation, and pulled open the wound. This wound, in healing the second time, was grooved, and caused the very large amount of astigmatism described.

In his series of fifty cases, Pfingst stated that no case accepted more than 6 D. cylinder, although one case had as much as 22 D. astigmatism shortly after the operation. In the case of 22 D. of astigmatism against the rule observed by me, the patient would not accept more than 8 D. cylinder at the first test, and, afterward, when the astigmatism had been reduced to 5 D., the patient accepted 4 D. cylinder, in conjunction with the sphere for distance, and 3.50 D. cylinder with the sphere for reading.

I have, however, seen one case where the patient accepted 16 D. cylinder twenty-seven days after the operation. It was a case where incarceration of the iris in the whole length of the wound had taken place; and still another case, in which 11.50 D. cylinder, combined with a 4 D. sphere, was accepted for constant wear and with comfort. In the latter case, the wound pulled open twice during the healing process, and left a deep groove. Both of these cases are reported in full farther on in this chapter.

One feature, of which Pfingst did not speak in his article, was the change in the axis of the astigmatism. I have found it to vary from five to thirty degrees in the first six weeks. This is to be accounted for by the healing process in the wound, the contraction of the scar, and, perhaps, to some extent, from the pressure of the lids during the healing. The axis of the astigmatism finally settled down to a definite place, just as the amount of the astigmatism did, after about six weeks' time.

Owing to the change, both in the amount and the axis of the astigmatism, after cataract extraction, only temporary glasses should be given till the end of the second month after the operation, and it is safer to wait for five or six months before giving permanent glasses.

The correct *adjustment* of glasses after cataract extraction, especially where both eyes have been operated upon, is an important matter. The adjustment for the distance or street glasses is quite different from that for the near or reading glasses. While the distance glasses should rest almost in the vertical plane, being very slightly tilted forward at the top to overcome spherical aberration, or a small amount of astigmatism, if present, and should be centered with the pupils, the glasses for the reading distance are to be decentered toward the nose, and should be worn at a lower plane or level than the distance glasses, in order to allow the patient to look through the center of them. If this adjustment is not given to the near glasses, they act as prisms, bases out, and cause diplopia for the near point in the horizontal plane; and, if not worn at a lower level than the distance glasses, they act as prisms, bases up, causing diplopia in the vertical plane — the combined action giving a crossed vertical diplopia.

Holden has given a working formula for the decentering of lenses, as follows: —

$$M = \frac{P \times 9}{D}$$

in which M is the number of millimeters of decentering that is required to give a lens, D, of a certain power, to get the effect of a prism, P, of a certain number of degrees. As he says: "For the effect of any prism, multiply 8.7 mm. [practically 9] by the number of that prism, and for any lens divide this product by the number of diopters of the lens."[1]

[1] Knapp's *Archives of Ophthalmology*, January, 1891, Vol. XX, pp. 1-25.

For example, say we have a lens of 6 D. in each eye, which we wish to decenter inwards, so as to act as prisms of 2°, bases in,

$$M = \frac{2 \times 9}{6} = 3,$$

the number of millimeters of decentering required to give such a lens (6 D.) so as to act as a 2° prism.

No displacement should be more than 7 mm. in each eye.

The practice that is, I regret to say, sometimes followed, of putting a distance glass in one side of a reversible spectacle frame, and the reading glass in the other side, where but one eye has been operated upon, and causing the patient to reverse the frames when he wishes to change from distant to near vision, is an exceedingly bad one; with such frames, it is impossible to give the correct adjustment, even with those that are reversed by turning on a vertical axis. I make it a rule, therefore, to give my cataract patients two pairs of glasses, one for the distance and one for the near point.

Spherical and *chromatic aberration* are other troublesome features, that are coincidental to the strong glasses necessary after cataract extraction, and must not be lost sight of. I wish to speak especially of spherical or monochromatic aberration, as it is sometimes called.

William Harkness[1] has shown that "with a pupil four mm. in diameter the normal cornea produces monochromatic aberration to the extent of $\frac{1}{33}$ (1.2 D.); and as there is no confusion of images in the normal eye, it seems probable that the crystalline lens exerts some compensating action. This suspicion is strengthened by the well-known fact that in aphakia the acuteness of vision is nearly always improved by giving a certain inclination to the powerful convex glasses which are necessary."

But the tilting of the strong convex glasses, necessary in cataract cases, serves not only to overcome this spherical

[1] Knapp's *Archives of Ophthalmology*, Bd. Vol. XII, p. 18.

aberration spoken of by Harkness, but also for correcting in part or whole the astigmatism usually present after cataract extraction. Since this astigmatism is generally against the rule, that is, the vertical meridian, or one near it, is made flatter by the contraction of the scar, it can be easily corrected by rotating the strong spherical glass on the horizontal axis, or one near to it, the rotation being greater or less according to the astigmatism to be corrected.

Dr. Green, of St. Louis, in a valuable and instructive paper, "An Elementary Discussion of some Cases of Centrical Refraction through Tipped Spectacle Lenses," *Transactions American Ophthalmological Society*, Bd. Vol. V., 1888–90, pp. 690–717, discusses the subject of tilting of lenses, both spherical and cylindrical, at length, and at the close of the paper gives a table showing the effect of tilting lenses a certain number of degrees. I give his conclusions and the table.

He says: "The change effected in the power of any lens by tipping may be summed up as follows: —

"Every spherical lens is increased in power in all its meridians; the rate of increase and the actual increase being greatest in the vertical and the least in the horizontal meridian. A spherical lens is, therefore, also rendered astigmatic, and the excess of increase in power in the vertical meridian over that in the horizontal, for any given inclination, is the measure of the astigmatism.

"Every convex or concave toric or sphero-cylindrical lens is increased in power in all its meridians. When the two principal meridians of the lens lie in the vertical and in the horizontal plane, respectively, the rate of increase in power is greatest in the vertical and least in the horizontal meridian; and when the power of the untipped lens is greatest in the vertical meridian the actual increase is also greatest in the vertical meridian, and the astigmatism of the lens is increased. When, on the other hand, the power of the untipped lens is

greatest in the horizontal meridian, the astigmatism of the lens is at first diminished, and since the possible increase in power in the horizontal meridian is limited, there is always some value of ϕ (the angle of tipping or inclination) at which the astigmatism of the lens is reduced to zero, and beyond which the direction of the meridians of greatest and least refraction is reversed.

"In the case of a tipped plano-cylindrical (or other equivalent) lens, the greatest increase in power is in the meridian at right angles to the axis of the lens, the power of the lens in the meridian of the axis remaining at zero, the rate of increase, and also the actual increase in power is greatest when the axis of the untipped lens is horizontal, and is least when the axis of the untipped lens is vertical."

The table that he gives shows the relative increase in power of a lens of given strength when tipped a certain number of degrees, beginning at the vertical where it is tipped no or zero degrees, and gradually increased to 90°. However, I may say, that it is not practicable to tip any lens more than 20°.

Table

Angle of Tipping	Sphere	Cylinder or Equivalent, Axis 180°	Cylinder or Equivalent, Axis 90°
zero	1.	1.	0.
5°	1.010	1.002	0.008
10°	1.042	1.010	0.032
15°	1.097	1.023	0.074
20°	1.179	1.041	0.138
25°	1.297	1.066	0.231
30°	1.462	1.096	0.366
35°	1.689	1.134	0.555
40°	2.008	1.178	0.830
45°	2.464	1.232	1.232
90°	infinity	2.236	infinity

Ward A. Holden, in a most excellent and practical article on this subject,[1] gives a working table for the tilting of lenses, wherein he not only shows the relative increase in power of a spherical lens by being tilted a certain number of degrees, but the actual increase in power of the lenses most commonly used after cataract extraction. I append the table, as it is of practical value.

TABLE

SPHERICAL, FOCUS IN INCHES	TILTING 10°	TILTING 15°	TILTING 20°
$4\frac{1}{2}$	$\frac{1}{180}$ +	$\frac{1}{52}$ −	$\frac{1}{40}$
4	$\frac{1}{160}$ +	$\frac{1}{52}$ +	$\frac{1}{26}$ −
$3\frac{1}{2}$	$\frac{1}{80}$ −	$\frac{1}{52}$ +	$\frac{1}{26}$ +
$3\frac{1}{4}$	$\frac{1}{80}$ −	$\frac{1}{40}$ −	$\frac{1}{22}$ −
3	$\frac{1}{80}$ −	$\frac{1}{40}$ +	$\frac{1}{22}$ +
$2\frac{3}{4}$	$\frac{1}{80}$ −	$\frac{1}{40}$ +	$\frac{1}{20}$ +
$2\frac{1}{2}$	$\frac{1}{80}$ +	$\frac{1}{32}$ −	$\frac{1}{18}$
$2\frac{1}{4}$	$\frac{1}{80}$ +	$\frac{1}{32}$	$\frac{1}{16}$ +

To give an example, say a spherical glass of $2\frac{1}{2}$ inch focus (16 D.), often given as a reading glass after cataract extraction, is tipped forward 10°, it would increase its strength in the vertical meridian .50 D.; if tipped 15°, it would increase its power in the vertical meridian 1.25 D.; and, if tipped 20°, it would increase its power in the vertical meridian 2.25 D. In each instance, however, it would also slightly increase the strength of the glass in the horizontal meridian. Now, if there was only a small amount of astigmatism against the rule, axis 180°, this could be easily corrected by tilting the strong plus spherical glass.

There is one disadvantage, incidental to the tipping of

[1] "On the Cylindrical Equivalent of Tilted Lenses, the Prismatic Equivalent of Decentered Lenses, and the Employment of such Lenses in Practice." Knapp's *Archives of Ophthalmology*, Vol. XX, pp. 1–25.

strong spherical glasses, which Holden points out. He says: "The spherical lens tilted on a horizontal axis has the disadvantage that the refractive error is corrected only while the eye remains in a given horizontal plane. Suppose the upper edge of the glass tilted from the patient. Then, if he look through the lower part of the glass, the visual axis of the eye comes to form a smaller angle with the axis of the lens, and the effect of the tilting is correspondingly lost. If he look through the upper part of the glass, the visual axis is at a greater angle with the axis of the lens, and the refractive power is increased. For this reason, tilted spherical lenses are less adapted for distance than for reading."[1]

Incidentally, it may be referred to again that myopic astigmatism *with the rule*, when associated with myopia of high degree, can be corrected by tilting the strong spherical glass on its horizontal axis. This follows from the fact that in compound myopic astigmatism with the rule, just as hypermetropic astigmatism against the rule, the meridian of greatest error lies in the vertical plane, or one near it; and, by tilting the strong sphere on its horizontal axis, it acts more strongly in the vertical plane than in the horizontal; and, in this way, small amounts of astigmatism can be corrected when associated with high degrees of spherical error. Except in very high degrees of myopia, 10 to 18 D., with astigmatism of small amount, 1 to 3 D., with the rule, this method should not be adopted; for, as pointed out by Donders:[2] "This means of correcting astigmatism is, however, capable of application only when relatively strong spherical glasses are required to neutralize the ametropia; and then, too, a more perfect correction will be attainable by cylindrical curvature of one of the surfaces. Only in aphakia can we advantageously, in my opinion, in order to correct a certain degree of astigmatism, make use of an oblique position of the glasses. Almost always it

[1] *Loc. cit.* [2] *Accommodation and Refraction of the Eye*, p. 511.

appears that when we give a certain inclination to the strongly convex glass the acuteness of vision is improved, and the necessity of attending strictly to this in every case of aphakia is generally recognized."

Before proceeding to give illustrative cases, I wish to speak very briefly of "toric" and "periscopic" lenses.

Toric Lenses. — Dr. John Green gives the following definition of a toric lens: "When a circle is revolved about a line in its own plane as an axis, a toric surface is generated. When the axis of revolution is a chord, other than a diameter of the generating circle, two toric surfaces are generated, by the greater and lesser arcs, respectively (Fig. 103, *A*). When the

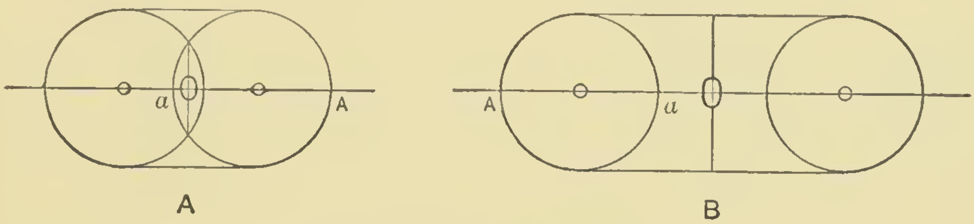


FIG. 103 (after John Green).

axis is taken outside the generating circle, the toric surface has the form of a ring (Fig. 103, *B*). The plane of the circumference described by the center of the generating circle cuts the toric surface *equatorially*. When the axis of revolution is taken outside the generating circle, this plane cuts the toric surface in two equatorial circles, a lesser and a greater, which have a common center at the point in which the equatorial plane cuts the axis of revolution, which point is the center of the torus. Every plane passing through the axis of revolution cuts the toric surface meridionally."[1]

A toric lens, then, is one whose two cylindrical surfaces, with different length radii, are ground on one side of a lens with their axes at right angles to each other. The other side of the lens may be plane, or have a plus or minus sphere

[1] *Transactions American Oph. Soc.*, Bd. Vol. V, 1888–90. pp. 690–717.

ground on it. Such glasses are especially applicable after cataract extraction, or in other cases when strong spheres have to be combined with cylinders. To give an example, say after cataract extraction a patient accepts + 10 D. + 4 D. cyl., 180°. Instead of giving this glass in the ordinary form, + 10 D. spherical ground on one side and + 4 D. cyl., 180°, on the other, it can be ground in the toric form, as follows: Grind + 5 D. sphere on one side, instead of the + 10 D., and on the other side + 9 D. cyl., 180°, + 5 D. cyl., 90°. To give another example, say a patient accepts + 14 D. + 5 D. cyl., 180°. It may be written in a toric lens thus: + 8 D. + 11 D. cyl., 180°, + 6 D. cyl., 90°. Such a combination makes a thinner glass, gives a wider field, causes less spherical aberration, and secures better vision, than the ordinary sphero-cylindrical glass. They are considerably more expensive than the ordinary glasses, but are much more preferable, and when the patient is able to pay for them should be prescribed. As a matter of fact, the profession has been tardy in recognizing the value of these glasses, for they are of signal advantage in many cases of refraction, even where no extraction has been performed, especially where the glasses are of a moderate or high power. Some examples will serve to illustrate their advantage.

(1) Compound hypermetropic astigmatism, where the patient accepts + 2 D. + 2 D. cyl., 90°. A favorable toric form into which it can be transposed is, – 2 D. + 4 D. cyl., 180° + 6 D. cyl., 90°; in which case the – 2 D. spherical glass is ground on one side and the plus cylinders at right angles on the other. Or, secondly, one side of the glass could be left plane and plus cylinders ground at right angles on the other, thus + 2 D. cyl., 180° + 4 D. cyl., 90°. Thirdly, part of the sphere only could be ground on one side and cross cylinders on the other, thus + 1 D. + 1 D. cyl., 180° + 3 D. cyl., 90°. The first of the three toric forms into which the ordinary glass

is converted is the best, as it gives a periscopic effect, of which we will speak presently under "periscopic" lenses.

(2) Simple hypermetropic astigmatism; patient accepts + 4 D. cyl., 90°. A good toric form of this is – 2 D. + 2 D. cyl., 180° + 6 D. cyl., 90°.

(3) Compound myopic astigmatism; patient accepts – 2 D. – 2 D. cyl., 180°. A good toric form is – 5 D. + 1 D. cyl., 180° + 3 D. cyl., 90°. Again, take a higher myopia; say the patient accepts – 8 D. – 2 D. cyl., 180°. Part of the minus sphere can be ground on one side, and part on the other side in conjunction with the minus cylinder as a torus; thus – 5 D. – 5 D. cyl., 180° – 3 D. cyl., 90°.

(4) Simple myopic astigmatism; patient accepts – 4 D. cyl., 180°. Toric as follows: – 5 D. + 5 D. cyl., 90° + 1 D. cyl., 180°.

(5) Mixed astigmatism; patient accepts – 2 D. cyl., 180° + 2 D. cyl., 90°. Toric as follows: – 4 D. + 6 D. cyl., 90° + 2 D. cyl., 180°.

Where the glasses are not too strong, in transposing them into the toric form, we usually make them periscopic in shape also; that is, we grind them in the form of a meniscus (see periscopic lenses immediately following). In this way the advantages of both forms (toric and periscopic) are gained. After cataract extraction and where astigmatism is present, the glasses are very heavy; here part of the plus sphere must be ground on one side, while the remainder of the sphere, together with the cylinder, may be ground on the other side in the form of a torus.

Dr. John Green, of St. Louis, and Dr. George C. Harlan, of Philadelphia, introduced toric lenses to the notice of the American profession, and made known by their writings[1] the advantages of such lenses over ordinary lenses. However, toric lenses have not met with the favor they so much deserve.

[1] Green, *Transactions American Oph. Soc.*, Bd. Vol. V., p. 709. Harlan, *Loc. cit.*, 1885, 1889.

Dr. George J. Bull,[1] of Paris, gives a full account of toric lenses in a late publication of his, and I refer my readers to the writings of Harlan, Green, and Bull for a full exposition of the subject.

Periscopic Lenses. — The term *periscopic* comes from two Greek words, *περί*, around, about, and *σκοπεῖν*, to see; that is, they are ground in such shape that the patient can see as well through the margin of the glass as through the center. The form of such glasses, therefore, is that of a meniscus; that is, concave on one side and convex on the other. If the concave side is more curved than the convex, it acts as a negative glass; and if the convex side is more curved than the concave, it acts as a convex glass.

Such glasses are not suitable after cataract extraction, or in high-power glasses of any kind, on account of their weight; but weak and moderately strong glasses should always be ground in this form (meniscus) in preference to the ordinary form. In private practice I usually order this form of glass. The following are a few examples by way of illustration: —

(1) Compound hypermetropic astigmatism; patient accepts + 2 D. + 2 D. cyl., 90°. Periscopic form: – 4 D. + 6 D. + 2 D. cyl., 90°.

(2) Simple hypermetropic astigmatism; patient accepts + 4 D. cyl., 90°. Periscopic form: – 4 D. + 4 D. + 4 D. cyl., 90°.

(3) Compound myopic astigmatism; patient accepts – 2 D. – 2 D. cyl., 180°. Periscopic form: –5 D. + 1 D. + 2 D. cyl., 90°.

(4) Simple myopic astigmatism; patient accepts – 4 D. cyl., 180°. Periscopic form: – 5 D. + 1 D. + 4 D. cyl., 90°.

(5) Mixed astigmatism; patient accepts – 2 D. cyl., 180° + 2 D. cyl., 90°. Periscopic form: – 4 D. + 2 D. + 4 D. cyl., 90°.

[1] Bull, *Lunettes et Pince-Nez*, Paris, G. Masson.

Even simple spherical glasses can be ground in the periscopic or meniscus form. For example, + 2 D. Periscopic form: − 2 D. + 4 D. Again, take a minus spherical glass, − 2 D. Periscopic form: − 4 D. + 2 D.

Illustrative Cases

In giving the following illustrative cases of astigmatism after cataract extraction, I have selected them from my private and hospital practice. I have also selected cases from the clinics of Professors Roosa, Webster, Emerson, Pomeroy, and Lewis, at the Manhattan Eye and Ear Hospital, who kindly allowed me to make use of any cases that I wished to. I may say here that these cases came under my personal observation while I was Interne at the Hospital.

In selecting illustrative cases, I have had two points in view: first, to show typical forms of astigmatism after cataract extraction; and, second, atypical and exceptional cases. In all of these cases, the ophthalmometer proved of the greatest possible value in recording the changes in the form of the cornea.

Case CXIX. *Astigmatism against the rule*, 3.50 *D.*, *axis* 180°, *two weeks after operation;* 1.50 *D.*, *axis* 180°, *six weeks after extraction; Patient accepts* + 10 *D.* + .75 *D. cyl.*, 180°, *and gets* $\frac{20}{15}$ *vision, six weeks after operation.* — October 6, 1890, Sarah S., aged sixty-one years, in good health, had a simple extraction of cataract from the left eye by Dr. Webster. Smooth operation, the eye did well, and the patient was discharged after three weeks' stay in the hospital.

Ophthalmometer. — Two weeks after operation, astigmatism against the rule, 3.50 D., axis 180°; three weeks, 3 D., 180°; six weeks, 1.50 D., 180°.

Test cards and trial lenses. — Two weeks,

$$\text{L. V.} = \tfrac{20}{40}\ \text{W.} + 8\ \text{D.} + 2.75\ \text{D. cyl.}, 180°.$$

The ophthalmoscope and oblique illumination showed a light membrane in the pupil. This was needled. Four weeks later, and six weeks after the extraction, the ophthalmometer showed but 1.50 D. of astigmatism against the rule, axis 180°. Patient accepted + 10 D. + .75 D. cyl., 180°, and got V. = $\frac{20}{15}$. Read Jaeger No. 1 at 12 inches with + 13 D. + .75 D. cyl., 180°. Both the distance and reading glasses were ordered.

In testing for cataract glasses, part or the whole of the spherical error should be corrected before attempting to correct the astigmatism, especially if the astigmatism be of small or only moderate degree. This conforms to the exception given in the first part of this book in fitting cases of astigmatism associated with high degrees of hypermetropia and myopia, except in cases where there has been a large amount of myopia before the operation. After cataract extraction the eye is rendered excessively hypermetropic, and, as a consequence, part of this spherical error has to be corrected before the effect of the cylindrical correction is appreciated.

For reasons already given in the first part of the chapter, the patient will not usually accept as strong cylindrical glasses as indicated by the ophthalmometer, even though the astigmatism be against the rule. The amount of the astigmatism after cataract extraction is not of as great importance as the axis; for, as we can have no spasm of accommodation to deal with, by simply increasing the strength of the spherical glasses, we soon arrive at the glasses that give the best vision, provided we have the correct axis at which to place the cylindrical glass. At least, this has been my experience. I have found the ophthalmometric the very best method of all the objective ones for keeping the record of the changes in the curvature of the cornea after cataract extraction.

CASE CXX. *Astigmatism of large amount, 8.50 D., against the rule, axis* 15°, *two weeks after operation: 7 D., axis* 180°, *seven weeks after operation;* $\frac{20}{70}$ *V. with* + 10 *D.* + 5 *D. cyl.,*

180°, *seven weeks after the operation.* — April 28, 1891, Israel K., aged forty-five years, in good health, had a simple extraction of cataract from the left eye by Dr. Roosa. The operation was without complication, the patient did well, and was discharged from the hospital at end of two weeks.

Ophthalmometer. — Two weeks after operation, astigmatism against the rule, 8.50 D., axis 15°; seven weeks, 7 D., axis 180°.

Test cards and trial lenses. — Two weeks,

$$\text{L. V.} = \tfrac{20}{200} \text{ W.} + 10 \text{ D.} + 6 \text{ D. cyl., } 15°.$$

The ophthalmoscope and oblique illumination showed a light membrane in the pupil.

Seven weeks after the operation, the patient accepted + 10 D. + 5 D. cyl., 180°, and got $\frac{20}{70}$ V.; and read Jaeger No. 2 at 10 inches with + 4 D. sphere added. Both the distance and reading glasses were ordered. The astigmatism in this case did not decrease as much as is usual after extraction, being reduced at the end of seven and one-half weeks only 1.50 D., that is, from 8.50 D. to 7 D. At the same time the axis changed from 15° to 180°, or the distance of 15°.

Case CXXI. *Astigmatism of large amount, 6 D., against the rule, two weeks after operation; Reduced to 1.50 D., two months after operation; Patient at that time accepted all of the astigmatism indicated by the ophthalmometer and got $\frac{20}{15}$ vision.* — November 4, 1896, Mrs. S. J. C., aged fifty-five years, in good health, had a simple extraction of cataract from the left eye by me at her home. The operation was without complication, and the patient was discharged on the sixteenth day.

Ophthalmometer. — Sixteenth day, astigmatism against the rule, 6 D., axis 150°; one month, 4 D., axis 150°; two and one-half months, 1.50 D., axis 15°.

Test cards and trial lenses. — Sixteenth day,

$$\text{L. V.} = \tfrac{20}{50} \text{ W.} + 10 \text{ D.} + 4 \text{ D. cyl., } 150°.$$

Ophthalmoscope and oblique illumination show a clear pupil.

Two and one-half months after the operation, the ophthalmometer showed astigmatism of only 1.50 D., which the patient accepted in full.

$$\text{L. V.} = \tfrac{20}{15}\ \text{W.} + 13\ \text{D.} + 1.50\ \text{D. cyl., } 150°.$$

Reads Jaeger No. 1 at 12 inches with + 17 D. + 1 D. cyl., 150°. Both the distance and reading glasses were ordered, which she has worn with comfort ever since, two and one-half years, and maintains the same good vision.

It will be noticed in this case that the cylinder had to be reduced in strength in the reading glass. The reason for this has already been discussed in this chapter.

CASE CXXII. *Astigmatism with the rule*, 1.50 *D., twelve days after operation; Astigmatism did not change in amount or axis; Patient accepted the full amount of astigmatism indicated by the instrument, and obtained* $\frac{20}{20}$ *V. when combined with the proper spherical glass.* — October 22, 1890, Julia A. W., aged sixty-five years, in fairly good health, had a simple extraction of cataract from the left eye by Dr. Pomeroy. The operation was without complication, and the patient was discharged on the twelfth day.

Ophthalmometer. — Twelve days, astigmatism with the rule, 1.50 D., axis 90°; one month, the instrument gave exactly the same reading again.

Test cards and trial lenses. — Twelve days,

$$\text{L. V.} = \tfrac{20}{40}\ \text{W.} + 11\ \text{D.} + 1.50\ \text{D. cyl., } 90°.$$

One month, the ophthalmometer gives the same reading as at first.

$$\text{L. V.} = \tfrac{20}{20}\ \text{W.} + 11\ \text{D.} + 1.50\ \text{D. cyl., } 90°.$$

Reads Jaeger No. 1 at 10 inches with + 5 D. added.

The ophthalmoseope and oblique illumination show a clear pupil. Both the distanee and reading glasses were ordered.

Tilting the glasses in this ease improved the vision very little, if any, sinee the astigmatism was in the horizontal meridian and the eylinder was worn with its axis at 90°. I have found the same thing true many times when the axis of the cylinder was several degrees distant from the horizontal meridian, for example, the ease immediately preceding this one.

CASE CXXIII. *Astigmatism against the rule,* 3 *D., three weeks after operation;* 1 *D., six weeks after operation; No cylinder accepted on the final test.* — September 21, 1891, George H., aged fifty years, in good health, had a simple extraetion of eataraet from the right eye by Dr. Emerson. The operation was without eomplieation, and the patient was diseharged at the end of three weeks.

Ophthalmometer. — Three weeks, astigmatism against the rule, 3 D., axis 180°; four weeks, 2.50 D., axis 180°; six weeks, 1 D., axis 180°.

Test cards and trial lenses. — Three weeks,

$$\text{R. V.} = \tfrac{20}{70}\ \text{W.} + 10\ \text{D.} + 2.50\ \text{D. cyl., } 180°.$$

Ophthalmoscope and oblique illumination show a elear pupil.

Six weeks, astigmatism equals 1 D., axis 180°.

$$\text{R. V.} = \tfrac{20}{30}\ \text{W.} + 11\ \text{D.}$$

Reads Jaeger No. 1 at 12 inches with + 15 D. No cylindrieal glass was aeeepted on this final test. Ordered both the distanee and reading glasses.

A slight tilting forward of the upper edge of the spherical glass in this ease made the vision better than with the eombination of any eylinder. Moreover, as the astigmatism was exaetly in the vertieal meridian, and against the rule, a simple tilting of the sphere on the horizontal axis was easily made.

CASE CXXIV. *Astigmatism of very large amount*, 16 *D.*, *against the rule, two and one-half weeks after operation ;* 4 *D.*, *three months after operation ; Patient accepts* 3.50 *D. cylinder with proper sphere and gets* $\frac{20}{40}$ *V., after three months.* — May 28, 1891, Bridget M., aged fifty-five years, in good health, had a simple extraction of cataract from the right eye by Dr. Emerson. The operation was without complication, and the patient was discharged two and one-half weeks after the operation.

Ophthalmometer. — Two and one-half weeks, astigmatism against the rule, 16 D., axis 180°; three months, 4 D., axis 180°.

Test cards and trial lenses. — Two and one-half weeks,

$$\text{R. V.} = \tfrac{20}{200} \text{ W.} + 6 \text{ D.} + 12 \text{ D. cyl., } 180°.$$

The ophthalmoscope and oblique illumination showed a clear pupil.

Three months,

$$\text{R. V.} = \tfrac{20}{40} \text{ W.} + 12 \text{ D.} + 3.50 \text{ D. cyl., } 180°.$$

Reads Jaeger No. 1 at 12 inches with + 4 D. added. Both the distance and reading glasses were ordered.

The very large amount of astigmatism, 16 D., in this case, was reduced to 4 D. in the course of three months' time. It was on account of this very large amount of astigmatism that we waited longer than usual before giving the final test, in order that it might be reduced to its lowest amount.

On the first test the patient accepted + 12 D. cylindrical glass and only + 6 D. spherical glass ; while at the final test the patient accepted + 12 D. spherical glass, and only + 3.50 D. cylindrical glass.

This illustrates a common occurrence after cataract extraction ; to wit, that as the cylinder diminishes in strength, the sphere, as a rule, increases in strength, and *vice versa*.

It may be asked how it was possible to measure so much astigmatism (16 D.) with the Javal ophthalmometer, when the

graduated mire has only eight steps on it, representing but 8 D. In such a case as this, it is necessary to note the position of the mires on the arc, which has diopter marks on its posterior edge, in the primary position ; and then again in the secondary position after the images have been made to touch again. The difference between the two numbers will give the number of diopters of astigmatism.

Say the movable mire (in the instrument with the single movable mire, the old one) stands at 26 in the horizontal meridian when the images of the mires touch ; 26 added to 20 (20 being the distance in diopters the fixed mire stands on the opposite side of the arc) equals 46 D., the refractive power of the cornea in the horizontal meridian. Then when the arc is turned to 90°, say the images separate, showing astigmatism against the rule, and that the movable mire has to be moved along the arc till it stands at 10 before the images touch again. This added to 20, the distance of the fixed mire, would give 30 D., the refractive power of the cornea in the vertical meridian. Now the difference between 46 and 30 D. = 16 D., the difference in refractive power of the two principal meridians, or the amount of the astigmatism.

Case CXXV. — *Astigmatism of large amount*, 15 *D.*, *against the rule*, *three weeks after the operation ; Reduced to* 13 *D. after two months*, *and only to* 12 *D. after one year and a half*, *leaving* 12 *D. astigmatism permanently ; Patient accepted* + 11.50 *D. cylinder combined with* 4 *D. sphere ; Axis of the astigmatism did not change in the first two months*, *but had made a change of* 15° *when seen in eighteen months.* — March 16, 1891, Julia G., aged seventy-seven, in good health, had a simple extraction of cataract from the left eye by Dr. G. M. Black.[1] The operation was without mishap, but during the course of healing the wound pulled open twice, and when finally healed there was a

[1] Ex-House Surgeon, Manhattan Eye and Ear Hospital.

deeply grooved scar at the site of incision. Pupil circular and central, but at time the patient was discharged, twenty-first day, there was a membrane in it. One month after the operation a needling was performed by Dr. Black, which was not successful, and three days later a second needling was done, this time leaving a clear pupil.

Ophthalmometer. — Three weeks, astigmatism against the rule, 15 D., axis 165°; two months, 13 D., axis 165°; eighteen months, 12 D., axis 180°.

The *ophthalmoscope* showed an opening in the membrane in the pupil 3 mm. long by 2 mm. broad; pupil central and circular.

Test cards and trial lenses. —

One month, L. V. = $\frac{20}{200}$ W. + 3 D. + 12 D. cyl., 165°.

Two months, L. V. = $\frac{20}{70}$ W. + 4 D. + 11.50 D. cyl., 165°.

On account of the very large amount of astigmatism present, due to the grooved wound, distance glasses only were ordered, + 4 D. + 11.50 D. cyl., 165°, and she was told to come for another test in four months. She returned after sixteen months, saying the glasses had been satisfactory until the last three months.

The ophthalmometer showed the astigmatism at this time, eighteen months after the extraction, to be 12 D., axis 180°, instead of 165°, as at first. There is still a decided groove at the upper margin of the cornea.

Test cards and trial lenses. —

L. V. = $\frac{20}{30}$ W. + 6.50 D. + 10.50 D. cyl., 180°.

Reads Jaeger No. 1 at 9 inches, with + 11 D. + 10. D. cyl., 180°. Both the distance and reading glasses were ordered.

It will be seen that the vision with this last glass was increased to $\frac{20}{30}$, while $\frac{20}{70}$ was the best vision to be obtained two months after the operation. Furthermore, the axis of the glass had to be changed 15°.

This change in the axis of the astigmatism did not take place until *after two months* following the operation. This I have seen in but one other case so long after the extraction. It will be noticed, too, that the strength of the spherical glass had to be increased as the strength of the cylinder was diminished, a point already noted above in other cases.

An 11.50 D. cylinder is the strongest cylindrical glass that I have ever seen worn; but in this case it gave the best vision, and I did not hesitate to order it. Even eighteen months after the operation, + 10.50 D. cylinder for distance, and + 10 D. cylinder for reading, in combination with spheres, had to be ordered.

Dr. Pfingst, already quoted, said that in his series of fifty cases none accepted more than a 6 D. cylinder, although in some of his cases the instrument showed as much as 22 D. of astigmatism shortly after extraction. This case, it will be seen, accepted a much stronger cylinder, and, moreover, wore it with comfort. It is an exceedingly rare case, however. But the next following case to be reported is even more remarkable as to the strength of cylinder accepted, 16 D. cyl., 15°, twenty-six days after the extraction. This glass was not given permanently. The large amount of astigmatism was due to folding of the iris along the whole length of the wound.

Case CXXVI. *Astigmatism of excessive amount*, 20 D., *against the rule, from incarceration of the iris in the wound during healing; Patient accepted* 16 D. *cyl., without any sphere, twenty-six days after extraction.* — January 17, 1891, R. S. D., aged seventy-three years, general health good, had a simple extraction of cataract from the right eye by Dr. Roosa. Two or three drops of vitreous were lost at time of the operation. During the healing process the upper half of the iris folded backward, the pupillary edge coming in contact with the ciliary body, while the upper or folded portion of the iris became incarcerated in the whole length of the wound, prevent-

ing the wound from healing smoothly. The patient was discharged after twenty-six days.

Ophthalmometer.—Twenty-sixth day, astigmatism against the rule, 20 D., axis 15°.

Test cards and trial lenses.—

$$\text{R. V.} = \tfrac{20}{200} \text{ W.} + 16 \text{ D. cyl., } 15°.$$

Ophthalmoscope and oblique illumination show a membrane in the pupil. The pupil is drawn upward so far that it looks as if an iridectomy had been done above.

This patient was instructed to return in a month to have a needling performed, but he did not come again, and he has been lost sight of. In regard to the excessive amount of astigmatism in this case, and the very strong cylinder accepted, it is fair to presume that the astigmatism did not diminish a great deal after the patient went from under observation; because the measurements were made on the twenty-sixth day after extraction, about one month, after which length of time the astigmatism, as a rule, changes but little, and after six weeks' time practically none.

A 16 D. cylinder is by far the strongest cylinder I have ever seen accepted. But this glass in the present case gave the best vision to be obtained. I would call to mind again, however, the case of Dodd (eye not aphakial), where he gave 28 D. as a cross-cylinder, as follows:—

$$- 12 \text{ D. cyl., } 95° + 16 \text{ D. cyl., } 5°.[1]$$

[1] The patient who accepted this phenomenal glass had had trachoma, and V. without correction was only $\frac{1}{30}$. The ophthalmometer showed astigmatism against the rule, 28 D., axis 5° + or 95° –. The refractive power of the cornea in the meridian at 5° was 60 D., and in the meridian at 95°, 32 D.; an excess in power of 17 D. in the meridian at 5°, and a deficiency of 11 D. in the meridian at 95°, from the average refractive power of the cornea, which is about 43 D. The patient had in addition to the mixed astigmatism (which was corneal) 5 D. of hypermetropia. This corneal correction (– 17 D. cyl., 95° + 11 D. cyl., 5°), added to an hypermetropia of 5 D. (– 12 D. cyl., 95° + 16 D. cyl., 5°),

CASE CXXVII. *Astigmatism of very large amount*, 22 D. *against the rule, two weeks after operation;* 5 D. *against the rule five months after operation, at which point it remained stationary; Change in axis of* 10° *during healing.* — February 19, 1898, Ann F., aged fifty-five, in good health, had a simple extraction of cataract from the left eye by me at the Manhattan Eye and Ear Hospital. The eye healed quickly, but on the seventh day the patient fell over backwards from a stool on which she was sitting and pulled the wound open. This healed again, but left a deeply grooved wound. The patient was discharged on the seventeenth day; pupil central and circular.

Ophthalmometer. — Seventeenth day, astigmatism against the rule, 22 D., axis 180°; one month, 12 D., axis 170°; five months, 5 D., axis 170°; one year, 5 D., axis 170°.

Test cards and trial lenses. —

Seventeen days,	L. V. = $\frac{20}{100}$ W.	+ 8 D. + 8	D. cyl., 180°.
One month,	L. V. = $\frac{20}{40}$ W.	+ 10 D. + 8	D. cyl., 170°.
Five months,	L. V. = $\frac{20}{20}$ W.	+ 12 D. + 3.50	D. cyl., 170°.

Jaeger No. 1 at 12 in., with + 16 D. + 3 D. cyl., 170°. Ordered both the distance and reading glasses. This patient was seen one year after the extraction, and the astigmatism had not changed after the first five months. Twenty-two diopters is the highest amount of astigmatism after a cataract extraction I have ever seen. Although the ophthalmometer registered this very great amount of astigmatism, at no time would the patient accept more than an 8 D. cyl.

gave the immense improvement in vision = $\frac{1}{2}$, or 15-fold better than the vision without the glass.

With his glasses the patient could read newspaper print and follow his trade, that of a shoemaker. The doctor remarked on the case that without the ophthalmometer he could not have fitted it correctly, because subjective tests alone, or even with the aid of the ophthalmoscope and retinoscope, would have been almost useless, in which I agree with him.

For a full report of the case, see *Ophthalmic Record*, Vol. V, p. 229.

Case CXXVIII. *Astigmatism against the rule*, 3 D., *two and one-half weeks after operation; Astigmatism with the rule*, 2 D., *three months after operation*, *which remained as such for about four years*, *when the patient was last seen; Ophthalmometer showed no corneal astigmatism whatever before the extraction.* — January 29, 1891, H. R. N., aged seventy-one years, in good health, had extraction of cataract, with iridectomy, from the left eye by Dr. Lewis. A mild iritis followed the extraction, but the patient made a good recovery, and was discharged on the eighteenth day.

Ophthalmometer. — Two and one-half weeks, astigmatism against the rule, 3 D., axis 180°; three months, astigmatism with the rule, 2 D., axis 90°; and three and one-half years later the astigmatism was the same exactly as to amount and axis.

Test cards and trial lenses. — Two and one-half weeks,

$$\text{L. V.} = \tfrac{20}{50}\ \text{W.} + 10\ \text{D.} + 1\ \text{D. cyl., } 180°.$$

Ophthalmoscope and oblique illumination showed a light membrane in the pupil. This was needled three months later. At time of needling the ophthalmometer showed that the astigmatism had changed from 3 D. against the rule to 2 D. with the rule, axis 90°. August 7, 1894, over three and one-half years later, the corneal astigmatism still remained 2 D., with the rule, and

$$\text{L. V.} = \tfrac{20}{30}\ \text{W.} + 9\ \text{D.} + 1\ \text{D. cyl., } 90°.$$

Jaeger No. 1 at 12 inches, with + 16 D. spherical glass.

Case CXXIX. *Astigmatism against the rule*, 10 D., *four weeks after operation; Six months after operation*, *astigmatism with the rule*, 4.50 D., *which four months later (and ten months after operation) had diminished to about* 1 D. *with the rule.* — April 6, 1891, Phœbe W., aged fifty-five years, in good health, after a preliminary iridectomy, had extraction of cataract from the right eye by Dr. Roosa. Iritis followed, moderately

severe. The patient was discharged on the twenty-eighth day.

Ophthalmometer. — Four weeks, astigmatism *against the rule*, 10 D., axis 180°; six months, astigmatism *with the rule*, 4.50 D., axis 75°.

Test cards and trial lenses.— Four weeks,

$$R.\ V. = \tfrac{20}{200}\ W. + 13\ D. + 8\ D.\ cyl.,\ 180°.$$

Ophthalmoscope and oblique illumination show a membrane in the pupil. Patient advised to have a needling performed, but she wished to wait some months. Six months later needling was performed, and one week after the needling,

$$R.\ V. = \tfrac{20}{50}\ W. + 12\ D. + 2.50\ D.\ cyl.,\ 75°.$$

Reads Jaeger No. 1 at 10 inches, with 3.50 D. sphere added. Four months later this patient was examined by Dr. Lewis, and he found the astigmatism to be about 1 D. with the rule, axis 60°; the vision had increased to $\frac{20}{40}$ W. + 10 D. sphere, the patient not accepting any cylinder.

This patient had had a cataract removed from the left eye, previously to the operation on the right eye, with a good result. The case is reported to show the remarkable change in the astigmatism that occurred in less than a year's time.

Case CXXX. *Astigmatism with the rule*, 4.50 D., *three and one-half weeks after operation; Changed to* 1.50 D. *against the rule, after three years, and remained thus at the end of five years from operation; Case remarkable also for acuteness of vision obtained*, $\frac{20}{10}$, *and for accommodative power after the extraction of the lens.* — January 27, 1894, Emil C., aged forty-two years, in good health, had extraction of a "black" cataract, with iridectomy, from the right eye by me at his home. The wound did not heal completely for a week, and only a very shallow anterior chamber formed, but at the end of the week the wound closed completely, and the eye recovered with the

remarkable vision of $\frac{20}{10}$ (Snellen). At the end of three months it was discovered that he had the power of accommodation in the eye; and for that reason the case was reported at length in the *Manhattan Eye and Ear Hospital Reports*, January, 1895. His vision at time of the operation was: —

$$R.\ V. = \tfrac{20}{70},\quad L.\ V = \tfrac{20}{40}.$$

Jaeger No. 12 at 10 inches right eye, and No. 9 at 10 inches left eye. Though his vision was so good by the Snellen test, he could not recognize friends or members of his own family on the street, had not worked for five years, and insisted on the operation being done.

Ophthalmometer. — Before the operation, astigmatism with the rule, .50 D., axis 90° + or 180° − in each eye; three and one-half weeks after the operation, astigmatism with the rule, 4.50 D., axis 90°; three months after the operation no astigmatism whatever; three years, astigmatism against the rule, 1.50 D., axis 5°, and five years after, exactly the same as at three years, both as to the amount and axis of the astigmatism.

Test cards and trial lenses. — Three and one-half weeks,

$$R.\ V. = \tfrac{20}{50}\ W. + 9\ D. + 3.50\ D.\ cyl.,\ 90°.$$

Three months, R. V. = $\frac{20}{10}$ W. + 11.50 D.

Jaeger No. 1 at 12 to 15 inches, with + 15.50 D.

The patient discarded the reading glasses after wearing them a few weeks, and wore the distance glasses for all purposes. With this distance glass (11.50 D.) he read $\frac{20}{10}$ − (Snellen), and Jaeger No. 1 from 8 to 22½ inches, without changing the position of the glass at all on his nose.

May 6, 1897, three years and four months after the operation, I made the following note in my case book: —

"Ophthalmometer, astigmatism against the rule, 1.50 D., axis 5°.

"R. V. + $\frac{20}{10}$ − W. + 10.50. D. + 1.50 D. cyl., 5°.

"Jaeger No. 1, with the same glass, from $8\frac{1}{2}$ to $22\frac{1}{2}$ inches."

When last examined, five years after the operation, the astigmatism was the same as at the end of three years, and the patient had vision $\frac{20}{15}$ – and still the power of accommodation. The ophthalmoscope and oblique illumination showed the fundus of the eye normal and the media perfectly clear. The pupil was oval (from iridectomy above) and free from membrane, except a very narrow strip at the margin.

CASE CXXXI. *Astigmatism with the rule*, 3 D., *three weeks after operation;* 1.50 D., *against the rule, three months after; Accepts* + 1 D., *cylindrical glass, with sphere for distance, but no cylinder for reading.* — November 26, 1890, M. R., aged forty-five years, in good health, had a simple extraction of cataract from the left eye by Dr. Webster. A mild iritis occurred during healing, but the patient made a good recovery and was discharged on the twenty-third day.

Ophthalmometer. — Three weeks, astigmatism with the rule, 3 D., axis 90°; three months, astigmatism against the rule, 1.50 D., 180°.

Test cards and trial lenses. —

Three weeks, L. V. = $\frac{20}{70}$ W. + 8.50 D. + 2.75 D. cyl., 90°.

Three months, L. V. = $\frac{20}{30}$ W. + 10.50 D. + 1 D. cyl., 180°.

Patient was given + 14 D. for near work, and + 10.50 D. + 1 D. cyl., 180° for the distance.

The ophthalmoscope and oblique illumination showed a clear pupil and media.

CASE CXXXII. *Astigmatism against the rule, with a change in the axis of* 30° *within one week's time, due perhaps to a stretching of the wound from needling, which was performed one month after the extraction.* — March 18, 1891, J. S., aged fifty-six years, good health, had a simple extraction of cataract from the left eye by Dr. Pomeroy. The iris was wounded at time of

the operation and iritis followed. The patient was discharged in one month.

Ophthalmometer. — One month, astigmatism against the rule, 4 D., axis 180°. Five weeks, and after needling one week previously, astigmatism against the rule, 3 D., axis 30°.

Test cards and trial lenses. —

$$\text{L. V.} = \tfrac{20}{70}\ \text{W.} + 10\ \text{D.} + 3\ \text{D. cyl., } 180°.$$

Ophthalmoscope and oblique illumination show a membrane in the pupil; needling performed. One week later,

$$\text{L. V.} = \tfrac{20}{70}\ \text{W.} + 9.50\ \text{D.} + 2.25\ \text{D. cyl., } 30°.$$

This patient unfortunately was not seen again at the clinic. The interesting point in the case is the marked change in the axis of the astigmatism after the needling, as much as 30°. This was due, I think, to stretching of one end of the wound, though it may have been from the uneven healing of the wound.

Case CXXXIII. *Astigmatism* 6 D., *axis* 45°; *Section was made directly above for the extraction, but the nasal side of the wound (left eye) broke open during a needling on the twelfth day; Ultimate vision* $\frac{20}{20}$. — October 8, 1890, E. B., aged fifty-three years, good health, had a simple extraction of cataract from the left eye by Dr. Webster. No accident during the operation, and the eye did well. Twelve days later, when Dr. Webster attempted to perform a needling, the patient squeezed the eye violently and opened the wound at the nasal extremity. Within four days the wound had healed again, but no further attempt to needle was tried until five months later, when a successful needling was performed.

Ophthalmometer. — Seventeenth day, astigmatism with the rule, 6 D., axis 45°; five months, 1.50 D., axis 45°.

Test cards and trial lenses. — Seventeenth day,

$$\text{L. V.} = \tfrac{20}{100}\ \text{W.} + 9\ \text{D.} + 6\ \text{D. cyl., } 45°.$$

The ophthalmoscope and oblique illumination show a membrane in the pupil.

Five months, and after needling,

$$\text{L. V.} = \tfrac{20}{20} \text{ W.} + 13 \text{ D.} + .50 \text{ D. cyl., } 45^\circ.$$

Reads Jaeger No. 1 at 10 inches, with + 18 D. sphere, without any cylinder. Both the reading and distance glasses were ordered.

As a rule, after cataract extraction, the axis of the correcting cylinder is worn horizontally with the direction of the wound; but exceptionally it has to be worn with its axis at right angles to the direction of the wound, as in the few cases where the astigmatism is with the rule after the operation for cataract. The usual position for the corneal section being directly above in cases of cataract extraction, the astigmatism that follows, in the great majority of cases, is against the rule, and requires the cylinder to be worn with its axis at or near 180°, or horizontally with the direction of the corneal section. The exceptions to this general rule are: First, where there has been a high degree of myopia, and the astigmatism is against the rule, a minus cylinder must be worn to correct the astigmatism, when the axis of the cylinder must be worn at or near 90°, or at right angles to the corneal section; second, where the astigmatism is with the rule after extraction, when the cylinders must be worn at or near 90°, or at right angles to the corneal section.

In the case last reported the section was directly above, but during an attempted needling the patient squeezed the eye violently and pulled the wound open at its nasal end (at a meridian near 135°), and the grooved wound that followed at this position caused the axis, or the meridians of greatest and weakest curvature, to be at 45° and 135° respectively. The ophthalmometer showed this to be so.

In making the section for cataract extraction, therefore,

unless some special reason comes to bear on the case, it should always be made directly above. The astigmatism that follows is usually in or near the vertical and horizontal meridians, and in nearly every case against the rule. We have already pointed out the advantage of tilting the strong plus spheres if the astigmatism is against the rule and affects the vertical meridian. If the astigmatism does not lie in the vertical meridian, or one near it, this tilting of the strong spheres is not of much advantage; hence, since we can in a measure determine the axis of the astigmatism after extraction by the location of our section, we should place it, as is usually done, directly above — the most favorable position.

Of course, the section for cataract extraction could be placed below, but the surgical and optical reasons against this are quite apparent. Even in making section for iridectomy in glaucoma we should, where it is possible, always make the section above. First, for the reasons given above as to the favorable form of astigmatism it causes; second, and most important, by the iridectomy being made above the coloboma in the iris is hidden almost completely by the upper lid, thereby causing less deformity and giving better vision by cutting off the excess of light and preventing diffusion circles, which would follow if the artificial pupil was made below where it could not be covered.

Some regard must be had, therefore, to the position of the section in cataract extraction, if we wish to do the best by our patients. Astigmatism with oblique axes, that is, with the chief meridians off from 90° and 180°, other things being equal, is always worse than the astigmatism where the vertical and horizontal meridians are at fault. Consequently, where we have a controlling influence on the axis of the astigmatism, we should exert it to the best advantage, and place it as near as possible in the vertical and horizontal meridians of the cornea.

There is one other class of cases of which I wish to speak

briefly before closing this chapter — I mean cases of myopia with cataract.

Dr. Percival[1] says some operators have expressed great surprise at the marked change in the refraction in such cases after cataract extraction, when, as a matter of fact, they should expect it. For instance, after the statistics given by Helmholtz, Donders, and others, he shows by calculation that an axial myopia of between 25 D. and 26 D. is entirely corrected by simply extracting the lens from such an eye.

Since it requires about + 11 D. to correct the emmetropic eye after cataract extraction, it would naturally be supposed that a myopia of 26 D., after cataract extraction, would require a lens representing the difference between – 26 D. and + 11 D. (– 15 D.) to correct it for the distance. But such is not the case, and Dr. Percival, after giving a table of such cases, remarks: —

"It will be noticed that the change in refraction due to the operation *increases with the previous degree of axial myopia.*"

In other words, the higher the degree of myopia before the operation, the greater the influence proportionally will the extraction of the cataract have on the correction of same. I reproduce, in part, his table. The length of the emmetropic eye in this table is 22.8 mm.

TABLE

Antero-Posterior Dimension, or Optic Axis	Power of Glass to Correct before Operation	Power of Glass to Correct after Extraction	Change in Refraction
23 mm.	– .50 D.	+ 11.2 D.	11.7 D.
26 mm.	– 9.9 D.	+ 7. D.	16.9 D.
29 mm.	– 19.2 D.	+ 2.9 D.	22.1 D.
32 mm.	– 28.50 D.	– 1.25 D.	27.3 D.

[1] Knapp's *Archives of Ophthalmology*, Bd. Vol. XXVI, pp. 1–4.

I give this table in order that those who are not acquainted with the facts in such cases, as regards the change of refraction by extraction of the lens from myopic eyes, may not make errors in correcting them; and so that they will not be at a loss to account for so marked a change in the refraction. Moreover, it may prove of value, and serve as a warning also, perhaps, to those who intend to, or do now, remove the transparent crystalline lens in high degrees of myopia.

I have never removed the transparent lens in the living subject, but those who advocate it claim that it can be safely done on *suitable* eyes; and that the eye, by the operative procedure, remains only slightly myopic, or may be rendered hypermetropic. They also claim that visual acuity is increased by the retinal images becoming larger, that the strain of convergence is lessened, and that congestion of the fundus is relieved. Certainly, some very favorable reports of cases of high degree of myopia treated by removal of the crystalline lens have been made in the last few years. However, while keeping in mind the advantages of this method of treatment of high myopia, we should not forget the contraindications and dangers of the operation.

Contraindications. — (1) Any degenerative changes in the choroid or retina, especially if these changes are near the macula; (2) Vitreous opacities, which usually indicate degenerative changes in the blood vessels; (3) Marked corneal opacities; (4) Myopia of less than 12 D.; (5) Any condition that contraindicates extraction of senile cataract, as trachoma, detachment of the retina, advanced age, etc.

The chief dangers of the operation itself are: (1) Intraocular hemorrhage; (2) Detachment of the retina.

When we consider that one of the contraindications to the operation is a myopia of less than 12 D., and another, and the most serious one, degenerative changes in the choroid and retina, and remember how few eyes there are with myopia of

more than 12 D., with sound fundi, it will be apparent how few really suitable eyes there are for the operation. Furthermore, to obtain that ideal condition, about 2 D. of myopia remaining after the operation, so that the patient would not need a glass for the near point, the eye must have had at least 30 D. of myopia before the operation. Now 30 D. of myopia is so rare as hardly ever to be met with, and when it is encountered, degenerative changes in the fundus are almost certain to be present in such a highly myopic eye, which contraindicate operative procedure. Hence the ideal sought for in these cases is clearly out of the question, theoretically at least, as shown by the table of Percival. Even to obtain emmetropia after the operation, theoretically, a myopia of 25 or 26 D. is necessary before the operation. Practically, as shown by Von Hippel and others, emmetropia may be obtained by extracting the lens (discission of course) in myopia of only 15 D.; and in myopia of 18 to 20 D., it is obtained in about 25 per cent of the cases.

The operative treatment of high degrees of myopia by the removal of the crystalline lens is still on trial, and time and experience must decide for or against it.

CHAPTER XI

EXCEPTIONAL CASES

By exceptional cases, I mean cases in which the result of subjective examinations of the visual power differs widely from the reading of the ophthalmometer, either as to the *axis* or *amount* of the astigmatism, or as to both, as found by subjective examination with the test cards and trial lenses. All cases wherein the reading of the instrument differs as much as 15°, as regards the axis, and as much as 1 D. as regards the amount (except after cataract extraction) of the astigmatism, as found by subjective and by other objective tests, I regard as exceptional. Such cases, in my experience, are relatively rare, and hence I regard them as exceptional.

Javal, as far back as 1882, in the examination of over one hundred eyes, found the total and the corneal astigmatism was the same except in four cases. But further and more extensive examinations since then have established the fact that the corneal astigmatism as measured by the ophthalmometer, and the total astigmatism, differ in amount to the extent of about .50 to .75 D. in the *great majority of cases.* When the corneal astigmatism is "with the rule," the total astigmatism is found to be less than the corneal by .50 to .75 D., and when the corneal astigmatism is "against the rule," the total astigmatism is found to be more than the corneal by .50 to .75 D. The axis of the total astigmatism usually coincides with that of the corneal, or to within 10°. Keeping these points in mind, and taking into account the amount of difference to be expected between the corneal and the total astigmatism, the subjective examination is made easy and satisfactory. In fact, as a general practice, in

patients forty years of age and over, a single test with the ophthalmometer and a subsequent test with test cards and trial lenses is quite sufficient examination in order to arrive at the right glasses to be given, and, of course, without a mydriatic.

In patients under forty years of age, two tests, as a rule, are enough, and seldom is it necessary to give three, even in cases of children, and then without a mydriatic, except in rare instances where spasm of accommodation is present (strabismus cases are, of course, here excluded). It has been my experience, taking cases as they come, that I get better results without a mydriatic than with it (with the exception above noted). The mydriatic, besides upsetting the natural relation between the accommodation and the convergence, often causes us to give the patient too strong a glass, and one which he will often not wear after coming from under the influence of the mydriatic. Therefore, except in cases of excessive and irregular action of the ciliary muscle (spasm of accommodation), I believe the practice of using mydriatics a bad one, and one to be avoided. My experience in thousands of cases has taught me this.

But even with careful testing by an experienced hand, both without and with a mydriatic, there are a few cases where the astigmatism indicated by the ophthalmometer differs widely from that found by further objective and subjective examination. Where such discrepancies occur, they are to be accounted for by one or more of the following causes: —

1. Error in observation.
2. Abnormal lenticular astigmatism, from whatever cause.
3. Position of the glasses in front of the eyes.
4. Angle *alpha*, and lack of centring of the cornea and the lens.
5. Astigmatism of the posterior surface of the cornea.
6. Contraction of the recti muscles.
7. Spherical aberration.
8. Imperfect instruments.

1. *Faulty observation.* — The discrepancy between the reading of the instrument and the astigmatism as found on subjective examination, which is due to faulty observation, of course is only an apparent one; and a second and more careful examination usually clears it up. A poor light or uneven position of the head in the head-rest accounts for many of these mistakes in observation. Again, and especially in the aged, or in case of children who have been crying, tears standing in the eyes often cause an incorrect estimate to be made. In fact, sometimes when the astigmatism is with the rule, if of small amount, it may appear to be against the rule. This seems to be brought about by the tears standing in the groove between the lower eyelid and the eyeball and encroaching on the lower half of the cornea. The anterior surface of the tears between the edge of the eyelid and cornea assume a *concave* shape, lessen the refraction of the cornea in the vertical meridian, and cause the instrument to read astigmatism against the rule, when there is actually a small amount of astigmatism with the rule. Where the astigmatism is of considerable amount and with the rule, it would be lessened to some extent by this cause; and if against the rule, increased to some extent.

That the tears can modify the refractive power of the eye there is no question, because, strictly speaking, the tears form the first refractive surface of the eye, since there is always a thin layer of tears on the front of the cornea to keep it moist. But this layer is so thin and in such close contact with the cornea, and moreover, having about the same index of refraction of the cornea, its influence is so weak that it may, as a rule, be neglected entirely (Hirschberg, *Centralbl. für med. Wissensch.*, 1874). However, when the tears collect in excess in the eye, so as to encroach upon the lower half of the cornea, they may materially affect the reading of the ophthalmometer.

2. *Lenticular astigmatism.* — Javal, Nordenson, Schiötz, and many observers since them, have established the fact that

lenticular astigmatism amounts as a rule to .50 to .75 D. This may be called the normal astigmatism of the lens, just as we have about the same amount of astigmatism normally present in the cornea. In fact, the two, as a rule, neutralize each other. The lenticular astigmatism may amount to 1 or 1.50 D., or even to 2 D., and, in rare exceptions, to even more. In a case of *lenticonus anterior* in my practice, reported in this chapter, it amounted to as much as 7.50 D! But this is a very rare case, only five or six cases of lenticonus anterior having been reported in all literature thus far.

Javal[1] has reported a case of lenticular astigmatism of 2 D.; Carl Weiland,[2] a case with similar amount; and George M. Black,[3] a lenticular astigmatism of 3.50 D. But all of these are exceptional cases. The lenticular astigmatism, as a rule, amounts to but .50 to .75 D., as proved by abundant statistics, whereby it is shown that, in actual practice, the corneal astigmatism is diminished or increased that amount, accordingly as the astigmatism is with or against the rule. The most reasonable explanation to be given for the necessity of deducting .50 to .75 D. from the reading of the instrument when the astigmatism is with the rule, and adding a like amount when the astigmatism is against the rule, is in the following assumption, to wit: That, in corneal astigmatism with the rule, there is usually associated a lenticular astigmatism of .50 to .75 D., in the *same* meridian, but of an *opposite* kind, thereby neutralizing that amount of the corneal astigmatism; and, in astigmatism against the rule, there is usually present a lenticular astigmatism of .50 to .75 D. in the *same* meridian and of the *same* kind, thereby adding that amount to the corneal astigmatism.[4]

[1] *Mémoires d'Ophtalmométre*, p. 121.

[2] Knapp's *Archives of Ophthalmology*, Vol. XXII, 1893.

[3] *Loc. cit.*, Vol. XXI, 1892.

[4] I am aware of the fact that this can be explained in another way, to wit: In corneal astigmatism, with the rule, the lenticular astigmatism might be of the *same* kind, but in the meridian at right angles to the corneal astigmatism;

In this place it is interesting to note how *regular* lenticular astigmatism is caused. It may be produced by an oblique position of the lens, by a slight displacement of the lens, as by sub-luxation, or by unequal curvature of its surfaces. *Irregular* lenticular astigmatism, together with a large amount of regular lenticular astigmatism, may be caused by a marked displacement of the lens, so that the edge of the lens lies in the pupillary space; by lenticular opacities, as in beginning cataract; and by lenticonus. We may have also a dynamic regular astigmatism produced by an unequal contraction of the ciliary muscle (Dobrowlsky, Javal).

Donders, in his classical book on refraction, has reported two cases of lenticular astigmatism; one (p. 532) "*from congenital eccentricity* of the *crystalline lens*";[1] and the other case (p. 536) due to an oblique position of the lens, with "no, or only slight, lateral displacement of the lens."

I have had the pleasure of observing one such case under especially advantageous circumstances, that is, in a case of *aniridia*. Here, because of the complete absence of the iris, the lens could be seen plainly. When the patient first came under observation the lens was vertical and not displaced at all, but in the course of eighteen months it became luxated upward to a slight extent (about 1½ mm.), and the upper edge of the lens was tilted backward. By reason of this, while the corneal astigmatism remained unchanged, the total astigmatism in the eighteen months increased 1.50 D. This case is reported in full farther on in this chapter.

in which case, if the meridian at error in both the cornea and lens were myopic in nature, a simple myopia of .50 to .75 D. would be produced. In corneal astigmatism against the rule (by this explanation) the lenticular astigmatism must be of an *opposite* kind and in the meridian at right angles to the corneal, if the total is to amount to more than the corneal. But I believe the first explanation more likely to be the true one, and, in fact, actual measurements (Donders) and cases reported show it to be true. See Case CXXXVI in support of it.

[1] In the full report of the case, Donders stated also that the lens "had an oblique position."

Again, lenticular astigmatism may be caused by the surface of the lens being unequally curved, just as in the cornea. Moreover, the principal meridians of the lens may not coincide with the principal meridians of the cornea, but "respecting this, however, nothing is with certainty known."[1] And this same observer, long ago, made measurements showing that the axes of the lenticular astigmatism often did not coincide with the axes of the corneal astigmatism. Nevertheless, he came to the conclusion, "*that with a high degree of asymmetry of the cornea asymmetry of the crystalline lens exists, acting in such a direction, that the astigmatism for the whole eye is nearly always less than that proceeding from the cornea.*"[2]

It is certain that, in almost all cases of astigmatism with the rule (and they go to make up the great majority of cases), the corneal astigmatism on the subjective examination is lessened from some cause, presumably by a lenticular astigmatism, whatever be the relative positions of the principal meridians of the cornea and the lens.

In young subjects, moreover, we may have a regular astigmatism (dynamic) of the lens, produced by an unequal contraction of the ciliary muscle. Dobrowlsky was the first to point this out, and Javal made the same observation later.

Such astigmatism is shown to exist by paralyzing the accommodation with atropine, when a corneal astigmatism, or part of it at least, which required no correction before paralysis, will accept a cylindrical glass; thus proving conclusively that the corneal astigmatism must have been corrected, in whole or part, by a lenticular astigmatism, which latter, as both Dobrowlsky and Javal state, is most probably due to an uneven or irregular contraction of the ciliary muscle.

Irregular lenticular astigmatism, together with a large amount of regular astigmatism, may be produced by a decided luxation of the lens, so that its edge or rim lies across the

[1] Donders, *Accommodation and Refraction of the Eye.* [2] *Loc. cit.*

center of the pupil. Luxation of the lens to such an extent not only produces irregular astigmatism, but causes diplopia by the half of the lens in the pupil acting as a prism. Moreover, the refraction of the rays of light is so different in the two halves of the pupil that everything is confused to the patient. In such cases, it is best, as a rule, to fit the aphakial part of the pupil, ignoring the half with the lens altogether, as the best vision is to be obtained by so doing. Such strong glasses blur the images completely for the part of the pupil with the lens in it, and this does away with diplopia, at least for the eyes singly, although it may be present when both eyes are used together.

Lenticular opacities, as in beginning cataract, produce irregular astigmatism, and often cause diplopia. This is due to the different sectors of the lens becoming unequally swollen or distorted, and thereby their foci made different, with the result that diplopia, or polyopia even for one eye, is often caused. Glasses do not improve vision much or any in such cases, and it is best to wait till the cataract forms, which as a rule quickly follows. There are a certain number of cases of diplopia and polyopia even which are not due to lenticular opacities, and which are entirely relieved by glasses. Dr. St. John Roosa, in his recent book, *Defective Eyesight*,[1] emphasizes this point, and reproduces some excellent figures of Dr. G. J. Bull's of Paris, by way of illustration. He says: "The double vision quite often seen in hypermetropia, or hypermetropic astigmatism, a diplopia which is not constant, may always be relieved by a correction of the error of refraction.

"Dr. G. J. Bull has shown that this so-called double vision is often to be described 'as the imperfect superposition of a series of faint multiples of the original letter.'[2] I believe that this is the correct view of quite a number of cases of *polyopia*

[1] The Macmillan Co., N. Y.

[2] *Trans. Oph. Soc. Unit. King.*, Vol. XVI, p. 204.

monocularis. It explains the ease with which such cases are treated by correction of the error of refraction. The observer who will make himself astigmatic to a considerable degree will, in an instant, recognize this doubling of vision, which is the result of an uncorrected error of refraction in the eye, and has nothing to do with insufficiency of the muscles."

Lenticonus may be the cause of irregular astigmatism, together with a large amount of regular astigmatism, though such cases are exceedingly rare.

3. *The position of the glass in front of the eye.* — Strictly speaking, the cylinder that corrects the astigmatism, as indicated by the ophthalmometer, should be worn in contact with the cornea. For obvious reasons this cannot be done. Glasses must be worn about one-half inch in front of the eyes. In low or moderate amounts of astigmatism, when not associated with a large amount of spherical error, this moving forward of the glasses one-half an inch does not alter the power of the glass much; but in very high degrees of astigmatism, especially when in addition there is a big amount of spherical error, pushing the glasses forward one-half inch has a great influence on its refractive power. This point has to be taken into consideration, and a proper reduction in the strength of the cylinder to be made on this account (see Chapter X for explanation).

For those who wish to pursue the matter further, I may say Weiland has discussed this point at length in Knapp's *Archives of Ophthalmology*, 1893.

4. *Angle alpha.* — This angle, as it is well known, is formed by the *visual line* and *optic axis*, the visual line usually cutting the cornea four or five degrees to the nasal side of the center of the cornea, while the optic axis cuts the cornea at its center.

Now, ordinarily, when measuring the eye for astigmatism, we do not measure the center or summit of the cornea, but a

point on the cornea about 5° to the nasal side of its center, or in the point cut by the visual line. This must necessarily be so, for we have the patient look directly into the center of the tube, and, of course, he directs the visual line to that point. To be exact, in measuring the astigmatism of the cornea, we should find the angle *alpha* first in degrees, then have the patient look a corresponding number of degrees to the nasal side when looking toward the tube of the ophthalmometer, when the center of the cornea would be brought into position to be measured. And that the astigmatism for the two points may be different at the two points has been shown by Helmholtz, Donders, Knapp, and others. Knapp, in his earliest investigations to determine the shape of the cornea, in one case showed that the refractive power of the cornea in one and the same meridian at a distance of 1.25 mm. from the center of the cornea (about 7°) varied as much as one-third diopter: and since the angle *alpha* may amount in exceptional instances to as much as 12°, it is easy to see how the astigmatism at that distance from the center of the cornea might vary from that at the center. In fact, where the astigmatism is of high amount and the angle *alpha* large, it can be shown clinically with the ophthalmometer that the astigmatism varies for the two points. Donders has shown that the surface of the cornea 15° from the center becomes rapidly flatter from that distance on to its periphery. When using the ophthalmometer of Javal and Schiötz, we do not measure the whole of the cornea, but only a small spot, about 12 to 15° (2.50 to 3 mm.) in diameter, with its center at the point on the cornea cut by the visual line. It can be readily understood that, if this point is 12° to the nasal side of the center of the cornea, the point from which the image of one of the mires is reflected, when measuring the horizontal meridian, must be still further from the center of the cornea. At such a great distance from the center of the cornea, the surface is considerably flatter than at

the center, and the error in measurement in such an instance would likely be considerable, especially if the astigmatism happened to be of high amount. Of course, it is altogether exceptional to have an angle *alpha* of 12°, because, as a matter of fact, it rarely amounts to more than 5°, and often not to more than 2° or 3°, and may therefore, except in very high degrees of astigmatism, be left out of consideration altogether. In the higher grades of astigmatism, as after cataract extraction, it must be taken into account.

By means of the disk of Placido on the ophthalmometer, with the degrees properly marked on it, the center of the cornea is easily measured by having the patient look at the circle marked with the corresponding number of degrees as the angle *alpha* — to the nasal side when the angle is positive, as it usually is, and to the temporal side when it is negative. And this is another reason why the Placido disk should not be removed from the instrument of Javal, and replaced by a plane black disk, as is now done by some instrument makers.

The lack of centering, or collimation, as it is sometimes called, of the refractive media of the eye (cornea and lens) is thus seen to be exaggerated by the angle *alpha*, that is, by the visual line not coinciding with the optic axis, but cutting both lens and cornea to the nasal side of their centers as a rule, though it may coincide with or even be to the temporal side of the optic axis on rare occasions. I may say the angle *gamma* also increases the error caused by the angle *alpha*. The eye would be a much more correct optical instrument if the visual line coincided with the optic axis. Even then, and after leaving out of the question axial ametropia, it would not likely be a perfect instrument, and that, too, on account of improper centering of its refractive surfaces. Helmholtz and Knapp both have shown that the summit of the crystalline lens does not always lie in the corneal (optic axis in practice) axis, but

may be as much as 2° to its temporal side. This, of course, would cause astigmatism.

The want of proper centering of the cornea and crystalline lens, and the angle *alpha*, must all be put down as causes of discrepancy in the astigmatism found by the ophthalmometer and that found by subjective examination.

5. *Astigmatism of the posterior surface of the cornea.* — The posterior surface of the cornea may be astigmatic, just as the anterior surface, rendered so by its principal meridians having unequal length of radii of curvature. Tscherning has invented an instrument, the ophthalmophakometer, for measuring the posterior surface of the cornea, also for measuring the surfaces of the lens. This instrument is described by A. Javal in Norris and Oliver's *System of Diseases of the Eye*, Vol. II, pages 135 and 136.

By actual measurements, the posterior surface of the cornea is shown to have a slightly shorter radius of curvature than the anterior surface. A. Javal, in commenting on the same, says: "The posterior surface of the cornea is found to diminish in curvature from the center toward the periphery, as in the case of the anterior surface, and in case of corneal asymmetry it appears also, as might be expected, to follow the asymmetry of the anterior surface. As a concave lens of asymmetrical curvature, the effect of the cornea is to compensate in some degree the astigmatism of the anterior corneal surface as measured by the ophthalmometer.

"The maximum compensation due to this cause, so far as has been observed, is about 1 D. (as estimated for an eye in which the total astigmatism measured about 6 D.)" [1]

6. *Contraction of the recti muscles.* — In a few cases the recti muscles can, by voluntary action, alter the corneal astigmatism. I have reported one such case in the *Manhattan Eye and Ear Hospital Reports*, January, 1895, where the patient had a cor-

[1] *Loc. cit.*, p. 137.

neal astigmatism with the rule .50 D. which he could, by voluntary action of the recti muscles, increase to 2 D. in the right eye, and to 1.50 D. in the left eye. When under a mydriatic he could still increase the astigmatism in the right eye to 1.50 D., and in the left eye to 1 D. The lids were held from the eye so they could have no influence.

This might be called a dynamic corneal astigmatism, just as we may have a dynamic lenticular astigmatism caused by an unequal contraction of the ciliary muscle.

7. *Spherical aberration.* — In very high degrees of astigmatism, the images of the mires are affected by spherical aberration, and on this account give too large an amount of astigmatism. Leroy and Reid have dwelt upon this point, and insist that the proper reduction in the amount of the astigmatism, as measured by the ophthalmometer, has to be made if it is to accord closely with that found on subjective examination.

8. *Imperfect instruments, either by reason of bad construction or poor adjustment.* — Sometimes the instruments themselves are at fault in construction or material, and do not make correct measurements on that account. For instance, because of a faulty adjustment of the bi-refractive prism in the telescope, I have seen the image of the mires, after having been put accurately in line with the axis of the telescope, that is, directly in the line of the crossing of the wires in the telescope, on rotation of the telescope for the second position, go nearly out of the field of the telescope, so that they could hardly be seen.

Again, through lack of adjusting the arc that carries the mires in the position that *exactly* coincides with the line of doubling of the bi-refractive prism, I have seen instruments in which the images of the mires could not be made to *line* at any position whatever. This was because of the faulty position of the arc in regard to the line of doubling

of the prism, which caused a permanent and fixed displacement of the images of the two mires in relation to each other.

Again, imperfect material as regards the prisms and the lenses at times make it necessary to have entirely new prisms and lenses put in to replace the old ones. Moreover, I have seen instruments which had very clear images at first (both the imported and the domestic), which finally became so weak and dim that correct observations could not be made with them.

The above eight causes of error in ophthalmometric examination, which are here given to account for the discrepancies that are sometimes found to exist between the astigmatism as measured by the ophthalmometer and that found on subjective examination, together with the exceptional cases herein reported, emphasize the importance of a subjective examination, in all cases, after using the ophthalmometer. Although in the great majority of cases the ophthalmometer measures the astigmatism to within .50 to .75 D., as to amount, and to within 5° as to axis, yet there are enough exceptional cases to demand a subjective examination in all cases. In doubtful cases we must make other objective tests besides those made with the ophthalmometer and ophthalmoscope, and, if need be, which is seldom indeed, a mydriatic should be used, when retinoscopy can be used to advantage.

(1) *Cases showing discrepancies as to the amount of the astigmatism.*

CASE CXXXIV. *Corneal astigmatism*, 2.50 D., *with the rule; Total astigmatism*, 1.25 *D., by subjective examination.*—Mrs. H. H., aged thirty years, in good health, has worn glasses for three or four years, consulted me on September 21, 1896, on account of headaches and pains in the eyes, especially after using the eyes for close work.

Ophthalmometer.—Astigmatism with the rule, 2.50 D., axis 90° + or 180° − in each eye.

Test cards and trial lenses. —

$$\text{R. V.} = \tfrac{20}{50} : \tfrac{20}{20} + \text{W.} - 1.25 \text{ D. cyl., } 180°.$$

$$\text{R. V.} = \tfrac{20}{50} : \tfrac{20}{20} + \text{W.} - 1.25 \text{ D. cyl., } 180°.$$

Reads Jaeger No. 1 from 7 to 15 inches.

Ophthalmoscope. — Em. at 180° and M. 1.50 D. at 90° in each eye.

A second and a third test did not change the glass, and the patient would not accept a stronger cylinder with improvement in vision. I had this patient under observation for more than two years, and when last seen the glasses were satisfactory and the patient using the eyes with comfort.

In this case 1.25 D. had to be deducted from the corneal astigmatism as measured by the ophthalmometer, or, what amounted to the same thing, the patient would not accept the cylinder to correct the astigmatism, as indicated by the instrument, by 1.25 D.

Case CXXXV. *Corneal astigmatism with the rule,* 1 *D. right and* 1.50 *D. left eye. Patient will accept no cylindrical glass; Antimetropia; Presbyopia.* — December 19, 1898, Mrs. K. E. H., aged forty-three years, in robust health, has never worn glasses, though she has seen poorly with the right eye since a child. She comes now for reading glasses.

Ophthalmometer. — Astigmatism with the rule, 1 D. 90° + or 180° – right eye, 1.50 D. 90° + or 180° – left eye.

Test cards and trial lenses. —

$$\text{R. V.} = \tfrac{6}{200} : \tfrac{20}{100} \text{ W.} - 13 \text{ D.}$$

$$\text{L. V.} = \tfrac{20}{20} : \text{will accept no glass.}$$

Reads Jaeger No. 1 from 8 to 20 inches, with + 1.25 D. sphere left eye; no single binocular vision, the patient using the left eye for both the distance and the near point.

Ophthalmoscope. — M. 13 D., with posterior staphyloma and choroidal changes right, Em. left eye.

In this case, in the good eye, there was a corneal astigmatism of 1.50 D., which was neutralized by a like amount of astigmatism within the eyeball, perhaps by a lenticular astigmatism of that amount. Be that as it may, the simple spherical glasses are perfectly satisfactory, a + 1.25 D. being ordered for each eye. Of course no attempt was made to fit the right, the glass being used for it merely to balance that in the left, the good eye.

CASE CXXXVI. *Congenital absence of the iris; Corneal astigmatism with the rule*, 1.50 *D. right and* 2 *D. left*, *axis* 5° *and* 175°, *respectively; Total astigmatism* 1. *D. each*, *with the same axes as the corneal astigmatism; In eighteen months' time the corneal astigmatism did not change*, *but the total increased to* 2.50 *D. in each eye*, *axis* 180° *each*, *due to slight luxation upward and tilting backward of the upper edges of the crystalline lenses.* — I have already reported this case[1] from which the account is now in the main taken. Annie M. B., aged six, was brought to me by her mother, April 12, 1897, to have glasses fitted. The mother states that soon after the birth of the child she noticed something peculiar about the eyes. As the patient grew up she avoided the bright lights and always squinted the eyelids when in the sunlight. The child has always enjoyed good health, and, except for the defect in the eyes, is sound. Since the birth of this, the first child, the mother has been delivered of two other children, sound in every respect. Both the father and mother are healthy and without defect, and the mother says this is the first member of either her or her husband's family thus afflicted. The father, mother, and two younger children are all slightly hypermetropic, while the patient has compound myopic astigmatism.

Examination of the eyes. — The ophthalmometer shows astigmatism with the rule, 1.50 D., axis 95° + or 5° − right

[1] *Post-Graduate*, November, 1898.

eye; 2. D. 85°+ or 175°− left eye. The ophthalmoscope shows complete absence of the iris in each eye, nothing but a very narrow pigment-ring at the extreme periphery of the cornea being present. Nothing of the ciliary processes can be seen either with the ophthalmoscope or by oblique illumination. The lenses are clear and circular, except a slight nick in the lower edge of the right. The vitreous is clear and the fundus normal in each. The fibres of the zonule of Zinn can be seen distinctly below and at the sides, but not so plainly above, as the lenses are slightly displaced upward. The diameter of the lenses can be seen with the ophthalmoscope to become distinctly smaller when the patient makes strong efforts at accommodation.

$$\text{R. V.} = \tfrac{20}{100} : \tfrac{20}{50} \text{ W.} - 4.50 \text{ D.} - 1 \text{ D. cyl., } 5°.$$

$$\text{L. V.} = \tfrac{20}{200} : \tfrac{20}{70} \text{ W.} - 5 \text{ D.} - 1 \text{ D. cyl., } 175°.$$

Reads Jaeger No. 2 at 8 inches with these glasses.

The above glasses, ground in No. 2 London-smoke glass, to keep the excessive light from the eyes, were ordered, and with these the patient has pursued her studies at school with comfort for eighteen months. I may say that neither stenopæic slit or puncture improved the vision. The tension of the eye has remained normal.

I presented the case before the New York Ophthalmological Society, October 10, 1898. The vision at that date was about the same as when the patient first came under observation. The corneal astigmatism remains exactly the same, but the total has increased considerably (1.50 D. in each eye) by reason of the lenses being displaced a little upward and the upper margins being tilted slightly backward. The myopia has increased to some extent. The patient now accepts − 5 D. − 2.50 D. cyl., 180° right, and − 6 D. − 2.50 D. cyl., 180° left. The lenses remain clear, but with a suspicion of faint striæ of opacity in

the lower halves. The luxation upward is not more than 1 to $1\frac{1}{2}$ mm., and not enough to cause diplopia.

In this case there is no question whatever of the increase of the total astigmatism being due to the slight luxation upward and tilting backward of the upper edge of the crystalline lens. The displacement and tilting of the lens could be plainly seen by reason of the absence of the iris. The ophthalmometer showed absolutely no increase in the corneal astigmatism.

This case, together with others reported, proves beyond question that lenticular astigmatism may be caused by an oblique position of the lens.

(2) *Cases showing variation as to the axes of the corneal astigmatism and total astigmatism.*

CASE CXXXVII. *Corneal astigmatism with the rule, axis* 90° + *or* 180° – *in each eye; Patient accepts minus cylindrical glasses, axis* 15° *right eye, and* 30° *left eye.* — October 12, 1895, Mr. C. H. D., aged 28 years, in good health, has worn glasses for six or seven years, consults me now because of redness of the eyelids and pain in the eyes.

Ophthalmometer. — Astigmatism with the rule, .75 D., axis 90° + or 180° – each eye.

Test cards and trial lenses. —

$$\text{R. V.} = \tfrac{20}{200} : \tfrac{20}{20} + \text{W.} - 3\text{ D.} - .50\text{ D. cyl.}, 15°.$$

$$\text{L. V.} = \tfrac{20}{200} : \tfrac{20}{20} + \text{W.} - 3\text{ D.} - .75\text{ D. cyl.}, 30°.$$

Reads Jaeger No. 1 from 5 to 18 inches.

Ophthalmoscope. — M. 4 D. in each eye. No fundus lesion.

On a second test the ophthalmometer gave the same reading as at first; however, the patient accepted the glasses as at first, that is, 15° and 30°, respectively, distant from the axis as indicated by the ophthalmometer. The glasses were satisfactory as long as the patient was under observation, which was about six months.

CASE CXXXVIII. *Ophthalmometer shows corneal astigmatism with the rule, 60° + or 150° − left eye; Patient accepts a plus cylinder axis 30°, that is, 30° distant from the point indicated by the instrument.* — Mrs. L. R., aged fifty years, has worn glasses for the last eight years, but none of them have been comfortable, and she comes now to see if she cannot get better glasses.

Ophthalmometer. — Astigmatism with the rule, 1 D., axis 90° + or 180° − right eye; 1 D., axis 60° + or 150° − left eye.

Test cards and trial lenses. —

R. V. = $\frac{20}{40}$: $\frac{20}{20}$ W. + .75 D. + .50 D. cyl., 90°.

L. V. = $\frac{20}{40}$: $\frac{20}{20}$ W. + .75 D. + .50 D. cyl., 30°.

Reads Jaeger No. 1 from 9 to 20 inches, with + 2 D. sphere added.

Ophthalmoscope. — H. 1.50 D. each.

Second test: ophthalmometer gave exactly the same reading as at the first test.

R. V. = $\frac{20}{40}$: $\frac{20}{20}$ W. + 1.25 D. + .50 D. cyl., 90°.

L. V. = $\frac{20}{40}$: $\frac{20}{20}$ W. + 1.50 D. + .50 D. cyl., 30°.

This last glass was ordered for distant vision, and + 2 D. sphere was added to it for reading.

(3) *Cases with discrepancies both as to the axis and the amount of the astigmatism.*

CASE CXXXIX. *Corneal astigmatism with the rule in each eye; Total astigmatism is against the rule and at different axis from that of the corneal astigmatism; Marked asthenopia; Relieved by the glasses accepted on subjective examination, which glasses were not according to the reading of the ophthalmometer.*— This case was examined by Dr. Kinney in his private practice, and it is through his courtesy that I am able to report it here. November 22, 1897, Mrs. S. L. M., aged thirty-eight, consulted

Dr. Kinney, complaining of headaches and a strained feeling in the eyes when she used them to any extent. She is in fairly good health, but is troubled with malaria.

Ophthalmometer. — Astigmatism with the rule, .50 D., axis 75° + or 165° — right eye; with the rule, .75 D., axis 105° + or 15° — left eye.

Test cards and trial lenses. —

$$\text{R. V.} = \tfrac{20}{20} : \tfrac{20}{15} + \text{W.} + .75 \text{ D. cyl., } 165°.$$

$$\text{L. V.} = \tfrac{20}{15} : \tfrac{20}{15} + \text{W.} + .50 \text{ D. cyl., } 165°.$$

Reads Jaeger No. 1 from 10 to 20 inches with the distance glasses.

Ophthalmoscope. — Showed hypermetropia of about 1 D. in each eye. Normal fundi, and no opacities in the refractive media that could be discovered.

Second and third tests resulted in the patient accepting exactly the same glasses as at the first one, and the glasses were prescribed. They have been worn with comfort for about eighteen months.

In this case the astigmatism differed considerably in amount. .75 D. in each after deducting .50 D. from the reading of the instrument for astigmatism with the rule. As to the axis, the principal meridians of the cornea and lens (assuming lenticular astigmatism against the rule to be the cause of the discrepancy) coincided in the right eye, yet the axis of the cylinder had to be worn at right angles to that indicated by the instrument, because the total astigmatism was *against the rule.* In the left eye the principal meridians of the cornea and lens did not coincide, because the cylinder, though worn against the rule, did not take the axis at right angles (at 15°) to the astigmatism indicated by the ophthalmometer with the rule, but at a position 30° distant from that meridian, that is, at 165°. Very likely, as has been proved by actual measurements in

some cases by Donders, this meridian represented a mean between the principal meridian of the cornea and lens.

CASE CXL. *Corneal astigmatism with the rule, .50 D.; Patient accepts .50 D. cylindrical glass against the rule in each eye.* — November 20, 1897, Emily S., aged thirty years, has worn glasses for three years, came to the clinic of Drs. Lewis and Van Fleet, at the Manhattan Eye and Ear Hospital, to be fitted with glasses. On examination I found the following conditions : —

Ophthalmometer. — Astigmatism with the rule, .50 D., axis 105° + or 15° – right eye; with the rule, .50 D., axis 75° + or 165° – left eye.

Test cards and trial lenses. —

R. V. = $\frac{20}{15}$ – : $\frac{20}{15}$ + W. + .50 D. cyl., 15°.

L. V. = $\frac{20}{15}$ – : $\frac{20}{15}$ + W. + .50 D. cyl., 165°.

Reads Jaeger No. 1 from $5\frac{1}{2}$ to 15 inches.

Ophthalmoscope. — H. 1 D. in each eye.

The patient accepted exactly the same glasses on a second test, though the ophthalmometer still showed corneal astigmatism, .50 D., with the rule. A plus .50 D. cyl., 15° right, and plus .50 D. cyl., 165° left, were ordered. They proved entirely comfortable.

Here the corneal astigmatism and the internal astigmatism had their principal meridians coinciding, but the lenticular astigmatism (assuming the internal astigmatism to be in the lens) exceeded the corneal astigmatism in amount by .50 D., hence reversed the nature of the astigmatism in the *total* amount, and required the cylinders to be worn with their axes exactly at right angles to the axes indicated by the ophthalmometer.

CASE CXLI. *Large amount of corneal astigmatism against the rule, with some irregular astigmatism; Patient accepted cross cylinders not at right angles to each other, the axis of the minus*

cylinder being worn 30° and that of the plus cylinder 45° removed from the point indicated by the ophthalmometer; Vision markedly improved with the glasses, and binocular single vision restored. — November 19, 1895, Mrs. Jacob H., aged thirty-seven years, in good health, but is of a nervous temperament, consulted me on account of a dacryoeystitis and for glasses. After the dacryocystitis was cured I fitted her with glasses. Previously to my fitting her she had worn correction for one eye only, the right.

Ophthalmometer. — Astigmatism with the rule, 1 D., axis 90° + or 180° – right eye; astigmatism against the rule, 8 D., axis 30° + or 120° –, with irregular astigmatism, left eye.

Test cards and trial lenses. —

$$\text{R. V.} = \tfrac{20}{30} : \tfrac{20}{20} \text{ W.} + .50 \text{ D. cyl., } 90°.$$

$$\text{L. V.} = \tfrac{20}{200} : \tfrac{20}{40} \text{ W.} - 4.50 \text{ D. cyl., } 90°.$$

Reads Jaeger No. 1 from 5 to 16 inches.

Ophthalmoscope. — H. 1 D. right eye, H. 1.50 D. at 90° and M. 5 D. at 180° left eye. The cornea (left) had somewhat the appearance of a conical cornea, and the shadows resembled somewhat those so characteristic of conical cornea; yet, on a side view of the cornea, no particular bulging of that membrane could be detected. The radii of curvature by the ophthalmometer in the principal meridians were but slightly shorter than those of the average cornea. There were no opacities of the media in either eye, and the fundus in each was normal.

Second test: the ophthalmometer gave exactly the same reading as at first.

$$\text{R. V.} = \tfrac{20}{30} : \tfrac{20}{20} + \text{ W.} + .75 \text{ D. cyl., } 90°.$$

$$\text{L. V.} = \tfrac{20}{200} : \tfrac{20}{40} \text{ W.} - 4.50 \text{ D. cyl., } 90° + 2 \text{ D. cyl., } 165°.$$

Ad. 12°, ab. 6°, sur. R. and L. 2°. Single binocular vision is present, both for the distance and the near point.

A third test corresponded with the second, and the glasses were ordered: $+.75$ D. cyl., 90° right, -4.50 D. cyl., 90° $+ 2$ D. cyl., 165° left.

I have kept this patient under observation for more than two years, and within a few months I have seen her husband, who tells me the glasses are still satisfactory and the patient comfortable.

Perhaps the *irregular* astigmatism present in this case is enough to account for the discrepancy between the reading of the instrument and the glasses accepted on the subjective examination.

Case CXLII. *Corneal astigmatism with the rule; Patient accepts cylindrical glasses against the rule.* — November 27, 1897, Miss M. S. came to the clinic at the Manhattan Eye and Ear Hospital, because of a marked asthenopia and blepharitis marginalis. She was examined by Dr. Kinney, and by his courtesy I was allowed to see the case and report the same here.

Ophthalmometer. — Astigmatism with the rule, .75 D., axis 75° + or 165° − right eye; .75 D., axis 105° + or 15° − left eye.

Test cards and trial lenses. —

$$\text{R. V.} = \tfrac{20}{30} : \tfrac{20}{15} \text{ W.} + .50 \text{ D. cyl., } 15°.$$

$$\text{L. V.} = \tfrac{20}{20} : \tfrac{20}{15} \text{ W.} + .25 \text{ D. cyl., } 105°.$$

Reads Jaeger No. 1 from 5 to 20 inches.

A second test corresponded in every particular with the first, most careful examination being made because of the discrepancy between the reading of the instrument and the astigmatism found by the subjective examination in the right eye. The glasses were ordered as accepted, and they gave comfort and relief from the asthenopia and blepharitis.

Case CXLIII. *Corneal astigmatism against the rule; Total astigmatism against the rule, but with the axis of the cylinder* 15° *from the point indicated by the instrument, right eye; No corneal astigmatism, but total astigmatism of* 1.25 *D., left eye.* — December

24, 1895, Dr. L. W. H., aged fifty years, in good health, gives a history of diplopia affecting the left eye alone (monocular) for the last two months. This diplopia is not constant, disappearing and then recurring for a few days. On the first appearance of the trouble in the left eye he had a mild conjunctivitis, but that is about well. No history of syphilis, rheumatism, or traumatism. On testing the muscles no insufficiencies were found.

Ophthalmometer. — Astigmatism against the rule, .25 D., axis 165° + or 75° − right eye; no corneal astigmatism left eye.

Test cards and trial lenses. —

R. V. = $\frac{20}{15}$: $\frac{20}{10}$ W. + .50 D. + .25 D. cyl., 180°.

L. V. = $\frac{20}{20}$: $\frac{20}{10}$ W. + 1.25 D. cyl., 30°.

Reads Jaeger No. 1 from 8 to 24 inches, with + 2 D. sphere added for presbyopia.

Ophthalmoscope. — H. .50 D. right eye; H. 1 D. at 120° and Em. at 30° left eye. No opacities could be detected in either lens, although in the left eye there seemed to be a wavering or shimmering of the light in looking at the fundus. That there was not much the matter with the refractive media is shown by the remarkable acute vision of the patient. One would naturally suspect a beginning cataract, to account for the occasional monocular diplopia, especially at his age, fifty years. As the doctor was from a neighboring state I have not been permitted to follow up the case. Roosa[1] claims that functional diplopia is often seen in hypermetropia and hypermetropic astigmatism, that it is not constant, and that it is always relieved by a correction of the error of refraction. (See full explanation on page 354.)

I prescribed the reading glasses for the patient, which were satisfactory at the time given.

[1] Roosa, *Defective Eyesight*, The Macmillan Co., N.Y.

Case CXLIV. *No corneal astigmatism right eye; Corneal astigmatism against the rule* 180° + *or* 90° − *left eye, but the patient accepts a plus cylinder at* 150° *instead of* 180° *as indicated by the ophthalmometer; Spasm of accommodation; Mydriatic used.* — November 8, 1898, Mr. G. D., aged eighteen, student, consulted me on account of redness and pain in the eyes. The patient is in good health, but is a close student, and his eyes hurt him most in the evening. On account of the conjunctivitis, I gave him an astringent wash and applied alum to the lids once a day for a few days before giving him a careful test for glasses.

Ophthalmometer. — No corneal astigmatism right eye; astigmatism against the rule, .25 D., axis 180° + or 90° − left eye.

Test cards and trial lenses. —

R. V. = $\frac{20}{20}$ − : $\frac{20}{20}$ + W. + .25 D. + .25 D. cyl., 180°.

L. V. = $\frac{20}{20}$ − : $\frac{20}{20}$ + W. + .50 D. cyl., 170°.

Reads Jaeger No. 1 from 4 to 18 inches.

Ophthalmoscope. — H. 1 D. each eye.

On a second test the ophthalmometer gave the same reading as at first, but the patient would not accept the axis of the cylinder as indicated by the instrument (left eye), but at 170° as on the first test. On this account, and because of the symptoms of spasm of accommodation, I advised a mydriatic, but the patient declined, saying he was willing to make a trial of the glasses without a mydriatic being used. I therefore ordered them. The glasses gave him comfort for about two months, so that he could pursue his studies, but at the end of that time he returned, complaining of headaches and pains in the eyes. At this time he consented to have a mydriatic used, and I paralyzed the accommodation with scopolamine, $\frac{1}{5}$ per cent. solution, instilled one drop, every five minutes, six consecutive times.

Ophthalmometer. — Astigmatism negative right eye; astigmatism against the rule, .25 D. 180° + or 90° – left eye.

Test cards and trial lenses. —

R. V. = $\frac{20}{100}$: $\frac{20}{15}$ W. + 1 D. + .25 D. cyl., 180°.

L. V. = $\frac{20}{100}$: $\frac{20}{15}$ W. + 1 D. + .25 D. cyl., 150°.

Ophthalmoscope. — H. 1 D. each.

Three days later the patient accepted + .75 D. + .25 D. cyl., 180° right, and + .75 D. + .25 D. cyl., 150° left, which were ordered. These glasses have given him entire comfort since, though he has used his eyes for long periods at a time.

The cylinder accepted in the left eye had its axis at 150°, or 30° distant from the point indicated by the ophthalmometer, after a mydriatic was used.

Case CXLV. — *Lenticonus anterior; Corneal astigmatism with the rule*, 2 *D. in each eye; Total astigmatism is against the rule*, 5.50 *D. in right, and* 4 *D. in the left eye; Vision greatly improved with glasses.* — December 2, 1895, Mr. J. L. H., aged fifty-seven, in good health, a lawyer, consulted me because of a severe migraine in the right side of his head, and pain in the right eye. Four days previously he had migraine in the right side of his head so severely that he was confined to his bed all of one day, and has been incapacitated for work ever since. The pain seems to radiate from the right side of his head to the right eye. He has had such attacks before, but not so badly. There is no redness of the eye, nor is there any plus tension, or any indication of glaucoma whatever. He has worn glasses for fifteen years for reading, with which he got fairly good vision. He has never seen very well for distance or near. He is now wearing for reading the cross-cylinders: + 2.50 D. cyl., 180° – 3 D. cyl., 90° right eye, and + 2.50 D. cyl., 180° – 1.50 D. cyl., 90° left eye.

Ophthalmometer. — Astigmatism with the rule, 2 D., axis 90° + or 180° – right eye; with the rule, 2 D., axis 75° + or 165° – left eye.

Test cards and trial lenses. —

$$\text{R. V.} = \tfrac{20}{200} : \tfrac{20}{100}\ \text{W.} - 2.50\ \text{D.} - 2.50\ \text{D. cyl., } 90°.$$

$$\text{L. V.} = \tfrac{20}{200} : \tfrac{20}{50}\ \text{W.} - 1.50\ \text{D.} - 2.50\ \text{D. cyl., } 75°.$$

Reads Jaeger No. 1 from 7 to 12 inches, with + 1 D., – 2.50 D. cyl., 90° right, and + 2 D. – 2.50 D. cyl., 75° left.

Because of the great discrepancy between the astigmatism, as indicated by the instrument, and that found on subjective examination, I immediately suspected some trouble with the lens, an incipient cataract perhaps. On examination with the ophthalmoscope I found no opacity of the lens whatever, but to my surprise a transparent protuberance of a conical shape on the front surface of the lens of each eye, somewhat like that represented in the accompanying diagram. The corneæ were perfectly clear, except for a very minute opacity just to the outer side of the center of the left. The shadows reflected from the pupil resembled in a marked degree the shadow-crescents seen in conical cornea. I could not get a double image of the fundus by the direct method with the ophthalmoscope, as did Webster in his case, the first of this kind reported; however, I did not have the pupil dilated as he did, and besides, the conicity was not so marked in my case as in his, so far as I can judge by reading the account of his case and looking at the excellent diagrams he gave.[1] With the indirect method, however, I got a

FIG. 104. — Diagram of the crystalline lens, enlarged, giving a side view. The front of the lens with protuberance on it is to the left.

[1] *Archives Ophthal. and Otol.*, Bd. Vol. IV, 1874–1875, p. 382.

decided diplopia of the retinal blood-vessels, both vertical and horizontal; also the parallactic movement by which the double images could be made to approach toward, or recede from, each other by the slightest movement of the ophthalmoscope or object lens. The fundus was normal in each eye.

On a second test the ophthalmometer gave exactly the same reading as at first.

Test cards and trial lenses. —

$$\text{R. V.} = \tfrac{20}{200} : \tfrac{20}{50} \text{ W.} - 5 \text{ D.} - 2.50 \text{ D. cyl., } 90°.$$

$$\text{L. V.} = \tfrac{20}{200} : \tfrac{20}{30} - \text{W.} - 1 \text{ D.} - 3 \text{ D. cyl., } 75°.$$

Reads Jaeger No. 1, 9 to 15 inches, with -1 D. -2.50 D. cyl., 90° right, $+3$ D. cyl., 165° left eye. These reading glasses were prescribed, and have been worn for more than three years with comfort; however, his daughter tells me that in the last few months he does not get along so well with them as at first.

This patient, according to the glasses which he was wearing when he came to me, had a total astigmatism in the right eye, 5.50 D., and in the left eye total astigmatism, 4 D., in each *against the rule.* The ophthalmometer, however, gave him astigmatism in each eye, 2 D., *with the rule.* Hence, the lens must have had an astigmatism of 7.50 D. in the right, and 6 D. in the left, against the rule in each, in order to have the total astigmatism amount to 5.50 D. right and 4 D. left, against the rule. According to my own tests when he came to me, he must have had a lenticular astigmatism *against the rule* of 4.50 D. right and 5 D. left, in order to have a total astigmatism against the rule of 2.5 D. right and 3 D. left, because he had 2 D. of corneal astigmatism *with the rule* in each eye.

The following five cases are given, not because of the discrepancy in the astigmatism as measured by the ophthalmometer

and that as found on subjective examination, but because they are exceptional as regards the general run of cases in refractive work.

CASE CXLVI. *Corneal astigmatism with the rule .25 D.; On subjective examination the patient accepted plus .25 D. cylindrical glasses against the rule; In four years' time the axis of the corneal astigmatism and the axis of the total astigmatism, as brought out by subjective examination, had changed* 30°. — February 8, 1894, H. D. R., aged thirty-one, in good health, is a civil engineer, and uses his eyes very hard in drawing, consulted me because of pains in the eyes and an occasional headache. He had a well-marked conjunctivitis, for which I prescribed an astringent wash, and treated a few days before testing for glasses.

Ophthalmometer. — Astigmatism with the rule, .25 D., axis 75° + or 165° – right eye; .25 D. axis 105° + or 15° – left eye.

Test cards and trial lenses. —

$$\text{R. V.} = \tfrac{20}{10} - : \tfrac{20}{10} \text{ W.} + .25 \text{ D. cyl., } 165°.$$

$$\text{L. V.} = \tfrac{20}{10} - : \tfrac{20}{10} \text{ W.} + .25 \text{ D. cyl., } 15°.$$

Reads Jaeger No. 1 from 4 to 24 inches.

Ophthalmoscope. — H. .50 D. each.

A second test ten days later resulted in the patient accepting exactly the same glasses as at the first test, and they were ordered for his close work.

These glasses gave him relief from asthenopia, and he continued to use them for almost five years. For the last year of this time his old symptoms, eye ache and headache, came back once in a while.

December 9, 1898, I saw him again.

Ophthalmometer. — Astigmatism against the rule, .25 D., axis 135° + or 45° – right eye; with the rule, .25 D., axis 45° + or 135° – left eye.

Test cards and trial lenses. —

R. V. = $\frac{20}{20}$: $\frac{20}{15}$ W. + .25 D. cyl., 135°.

L. V. = $\frac{20}{20}$: $\frac{20}{15}$ W. + .25 D. cyl., 45°.

Reads Jaeger No. 1 from 6 to 20 inches.

Ophthalmoscope. — H. .50 D. each.

Four days later a second test, objective and subjective, corresponded exactly with the previous test, and the glasses were ordered. He has worn them for four months with entire relief from his asthenopic symptoms.

In this case, both the corneal and total astigmatism changed axes and in the same direction, and to the extent of 30°.

CASE CXLVII. — *Corneal astigmatism with the rule, with the principal meridians not at right angles.* — April 30, 1897, Miss N. S., aged twenty-five, in good health, has worn glasses off and on for the last ten years, but none of the glasses have given her relief from a very troublesome asthenopia. She was fitted with glasses twice under the influence of a mydriatic.

Ophthalmometer. — Astigmatism with the rule, 1 D., the images lining at 165° in first position, and at 60° in second position, right eye ; .75 D., the images lining at 15° in the first position, and at 120° in second position, left eye.

Test cards and trial lenses. —

R. V. = $\frac{20}{30}$: $\frac{20}{20}$ W. + 1.75 D. + .50 D. cyl., 60°.

L. V. = $\frac{20}{30}$: $\frac{20}{20}$ W. + 1.25 D. + .50 D. cyl., 120°.

Reads Jaeger No. 1 from 6 to 20 inches.

Ophthalmoscope. — H. 2.50 D. right eye, H. 2 D. left eye ; normal fundi, no opacities in the corneæ or lenses.

A second and third test resulted in the patient accepting the same glasses exactly as at the first test. The ophthalmometer gave the same reading in the three tests. The glasses were ordered, and gave immediate and continued relief from

the asthenopia. I saw the patient in March, 1899 (two years after), when she informed me that she had used her eyes constantly as an artist, and that the glasses were still entirely satisfactory.

CASE CXLVIII. *Corneal astigmatism with the principal meridians not at right angles in the right eye, but at right angles in the left eye.* — Mrs. J. E. M., aged fifty-eight years, in good health, consulted me because her eyes, after using them for close work, got a "sore feeling" in them and became red, especially the right one. She has worn glasses for a number of years; the last pair, + 2.25 D. spheres, she has worn for eight years.

Ophthalmometer. — Astigmatism with the rule, 1. D., the images lining at 180° in first position, and at 75° in the second position, right eye; .50 D., axis 90° + or 180° − left eye.

Test cards and trial lenses. —

R. V. = $\frac{20}{20}$ − : $\frac{20}{20}$ W. − .50 D. cyl., 180°.

L. V. = $\frac{20}{20}$ − : not improved with any glass.

Reads Jaeger No. 1 from 8 to 16 inches, with plus 3 D. sphere added.

Ophthalmoscope. — Em. in each eye apparently. There is no opacity of the lenses or the corneæ, and fundi are normal.

The reading glasses were ordered, + 2.50 D. + .50 D. cyl., 90° right, and + 3 D. sphere left. These glasses relieved the asthenopia, and she no longer complained of the sore and strained feeling in the right eye.

Both in this case and in the one immediately preceding it, the cylinders accepted were not at right angles to the meridian at error. For instance, in the right eye, in Case CXLVII, the cylinder was accepted with its axis at 60°, while the least curved meridian was at 165°, as shown by the images lining at that point, and, to be worn at right angles, its axis should have been at 75°; while in the left eye the plus cylinder was

accepted at 120°, but the least curved meridian, which it was given to correct, was at 15°.

And so in the present case, in the right eye, the most curved meridian was found at 75°, that being the second position and the images overlapping; nevertheless, the patient accepted a minus cylinder, axis 180°, while it should have been worn at 165°, to be at right angles to 75°.

I may say, however, that in some cases, where the principal meridians are not at right angles, I have seen the patient accept the cylinders with their axes exactly at right angles to the meridians at error. So it is well in such cases to try the cylinders at both the positions indicated by the ophthalmometer, and 15°, or at any number of degrees of inclination the chief meridians have toward each other from that of a right angle.

CASE CXLIX. *Large amount of astigmatism, the corneal and total corresponding closely as to amount and exactly as to axis; Patient accepts the glasses as indicated by the ophthalmometer with marked improvement in vision, but cannot wear any cylindrical correction, preferring simple spheres.* — March 27, 1893, Miss K. N., aged thirty-seven years, in good health, came to me for glasses. She has worn spherical glasses for close work, but not for distance, for ten years. None of them have ever been entirely comfortable to the eyes. She complains now of occasional headache and pains in the eyes, especially in the afternoon and evening.

Ophthalmometer. — Astigmatism with the rule, 1.25 D., axis 120° + or 30° − right eye; 5.50 D., axis 80° + or 170° − left eye.

Test cards and trial lenses. —

$$\text{R. V.} = \tfrac{20}{30} : \tfrac{20}{20} \text{ W.} + \ .75 \text{ D. cyl., } 120°.$$

$$\text{L. V.} = \tfrac{10}{200} : \tfrac{20}{50} \text{ W.} + 4.50 \text{ D. cyl., } 80°.$$

Reads Jaeger No. 1 from 8 to 15 inches.

Ophthalmoscope. — Em. at 120° and H. 1 D. at 30° right eye; Em. at 75° and H. 5 D. at 165° left. No opacities of the cornea or lens in either eye, and no abnormal condition of the fundus could be detected in either eye. No muscle insufficiency.

A second test was given, and as the patient accepted the same glasses as at first, they were ordered.

The patient tried faithfully to wear them for two months, but claimed they did not help her in the least, in fact, that they made the vision worse, because they elongated objects very much in the horizontal meridian. A simple + 2 D. sphere in each eye gave her more comfort than any other glasses, and these she continued to wear till her death four years later.

In this case, as well as the one to follow, little or no discrepancy in the axis and in the amount of the astigmatism, as measured by the ophthalmometer and that found on subjective examination, existed, nevertheless, the patients were not able to wear any cylindrical correction whatever. In seeking an explanation of the behavior of the eyes in these two cases, and in the others like them, which cases, I may say, are found in later life, in presbyopes, as a rule, who have never worn any correction in early life, or only a spherical one, though highly astigmatic, I can do no better than quote the words of Donders on the action of cylinders in general in the correction of astigmatism, and then make a deduction from them in reference to the cases here under consideration. He says: —

"The correction of regular astigmatism by means of cylindrical glasses is incapable of absolute perfection. Apart from the amblyopia, which, independently of the light-refracting system, complicates many cases of astigmatism, the acuteness of vision must, even with the most accurate correction, leave something to be desired, because the asymmetry of the astigmatic eye cannot be completely counteracted by the presence of a cylindrical lens. Moreover, the correction is only of that nature that the posterior focal points for the different meridians are brought together without the same

being true of the other cardinal points. The absolute coincidence of the nodal points in the different meridians is scarcely attainable. If they lie in the principal meridian of slightest curvature more posteriorly, correction with a biconvex cylindrical lens brings them more forward than those in the meridian of greatest curvature; and *vice versa* if they be situated more anteriorly, on correction by a biconcave cylindrical lens, they are moved more backward. In this is implied that the form of the bodies, on correction of astigmatism, is elongated in a direction opposite to that in which, before correction, elongation existed," etc.[1]

In other words, in cases of high degrees of astigmatism, which have gone without correction till late in life, the subjects have become accustomed to images of objects much elongated in a certain direction, and when we come to correct the astigmatism in these cases we greatly elongate the images in exactly the other direction, or the elongation is in the direction at right angles to what it was before correction. This is so disturbing and so upsetting to all previous ideas of the form and size of objects, that some patients simply will not have it, even though the vision, so far as test-types are concerned, is greatly improved by them, as witness the two cases here reported. Furthermore, the axes of the astigmatism in both of my cases were oblique (and against the rule in one case), and this of itself made it much more difficult for them to get used to the cylinders ; in fact, they could not, or would not, wear the cylindrical correction.

Case CL. *Corneal astigmatism against the rule, with oblique or slanting axis; Total astigmatism exactly the same as to axis and almost identical as to amount; Patient's vision is greatly improved with cylindrical correction, yet he cannot wear it.*— April 2, 1897, Mr. G. H. W., aged sixty-eight years, in very good health considering his years, consulted me for reading glasses. He has never worn glasses for the distance, but has worn simple spherical glasses for near vision since he was

[1] *Loc. cit.*, p. 509.

forty-five years old, with which he has gotten along fairly well, though his vision has always been rather poor.

Ophthalmometer. — Astigmatism against the rule, 2.50 D., axis 5° + or 95° – right eye; against the rule, .50 D., axis 170° + or 80° – left eye.

Test cards and trial lenses. —

R. V. = $\frac{15}{200}$: $\frac{20}{50}$ W. + 2.50 D. cyl., 5°.

L. V. = $\frac{20}{100}$: $\frac{20}{20}$ W. + 1.50 D. + .75 D. cyl., 170°.

Reads Jaeger No. 1 from 9 to 20 inches, with + 4 D. sphere added.

Ophthalmoscope. — H. 2 D. at 90° and Em. at 180° right eye; H. 2 D. at 90° and H. 1 D. at 180° left; normal fundi; no opacities of the refractive media.

The reading glasses were prescribed, and the patient made persistent efforts to use them for six weeks, but finally gave them up because of the great disturbance caused by the elongation of images in the vertical meridian. With simple spherical glasses he got tolerably clear vision for the reading distance, print appearing natural, if not so distinct as with the cylindrical correction; and he much preferred and was more satisfied with the spherical correction.

APPENDIX

IMPROVEMENTS ON THE JAVAL-SCHIÖTZ OPHTHALMOMETER: (*a*) DAVIS'S DOUBLE-MOVABLE MIRES; (*b*) VALK'S GEAR-WHEEL ATTACHMENT; (*c*) SKEEL'S PERPENDICULAR LEVER ADJUSTMENT; (*d*) METAL BASE AND OTHER MINOR IMPROVEMENTS. — REID'S OPHTHALMOMETER, A DESCRIPTION OF IT AND HOW TO USE THE INSTRUMENT. — OTHER OPHTHALMOMETERS

Davis's Double-movable Mires for Javal-Schiötz's Ophthalmometer [1]

By the term "double-movable mires" I mean that both mires, or reflectors (the graduated and rectangular), move at the same time and to an equal extent, and not one (graduated), as in the old instrument, while the other (rectangular) remains fixed 20° from the center of the arc. The advantage of having both mires move instead of one is that in so doing both mires are kept the same distance from the center of the arc, and their images the same distance from any point on the cornea that is being measured; whereas, as the old instruments are constructed, one mire (rectangular) remains fixed at 20° from the center of the arc on one side, while the graduated mire on the other side is required to do all the moving. This is very well if the point on the cornea happens to be of just sufficient radius of curvature in the meridian being measured to allow the image of the movable graduated mire to just touch the image of the rectangular mire when the graduated mire reaches the twenty-degree mark on its respective side of the arc. The mires would then be at an equal distance from the center of the arc, and their images, consequently, at equal distances from the point on the cornea measured. If, however, the meridian of the cornea under measurement is of such radius of curvature

[1] Reprinted from the *New York Medical Journal*, February 16, 1895.

as to allow the graduated mire to come closer than 20° on its respective side of the arc before the images of the mires touch, its image must necessarily be formed on the surface of the cornea nearer the point measured. On the other hand, if the meridian under measurement is of such radius of curvature that the images of the two mires approximate before the graduated mire reaches the twenty-degree mark on its side of the arc, then its image will, of course, be formed on the surface of the cornea at a greater distance from the point measured than the image from the rectangular mire, which is fixed at 20° on the opposite side of the arc. I think my point is clear. Now, since the human cornea (its apex, or point on it where the visual line intersects its surface) is very rarely of just the radius of curvature to allow the graduated mire to come exactly to 20° on its respective side, — the same distance as the fixed mire on the opposite side, — in order to have the images touch, any improvement that keeps both mires at the same distance from the center of the arc in every case, whatsoever the curvature of the cornea may be, is a decided advantage. The double-movable mires accomplish this perfectly.

Those who are only fairly well acquainted with the use of the ophthalmometer are aware of the fact that not the whole of the cornea is measured in an ordinary ophthalmometric examination, but only a very small portion of it — a space only of 2½ to 3 mm. in diameter. Furthermore, the center of this space does not coincide with the center of the cornea, except when the visual line coincides with the long axis of the cornea,[1] but with that point on the cornea intersected by the visual line, which point is usually a little to the nasal side of the center of the cornea, and, as a rule, on a horizontal line with it. Or, again, this point may lie to the temporal side of the corneal center. The space included between this visual line and the optic axis, forward from the point where they cross, is the well-known angle *alpha*, which is positive, nil, or negative, accordingly as the visual line lies to the nasal side of, coincides with, or is toward the temporal side of the optic axis. When the angle *alpha* is nil or very small, as it is in the majority of cases, the center of the small space measured on the cornea practically coincides with the center of the cornea, and the measurements of the ophthalmometer in such cases, with the proper restrictions, as

[1] Practically the same as the optic axis.

laid down by Javal, agree usually with the glasses accepted by the patient. When, however, this angle is large, especially when there is a large amount of astigmatism associated with a high degree of hypermetropia or myopia, the readings of the ophthalmometer do not correspond so closely with the subjective test. For example, in the natural eye, with a radius of curvature of 8 mm., an angle *alpha* of 6° is 0.9 mm., or, practically, 1 mm.; and, with an angle *alpha* of 12°, it would, of course, be 2 mm. In such a case, therefore, the point on the cornea measured by the ophthalmometer would be 2 mm. distant from the center of the cornea to the nasal or temporal side, accordingly as the angle is positive or negative. Now, the two chief radii of curvature at this point may be considerably different from the radii of curvature at the apex, — either one or both of them. To simplify matters, we will assume that in a given case the radius of curvature changes in but one of the chief meridians, — that of the vertical, — while it remains unchanged in the horizontal. Let the radius of curvature of the horizontal meridian at the apex be 8 mm., and that of the vertical meridian 7.61 mm. According to Javal's formula, $D = 1000 \frac{(n-1)}{r}$, the astigmatism at the apex in such a case is 2 D. Say, however, at 2 mm. distant from the apex the radius of the vertical meridian changes from 7.61 mm. to 7.31 mm., while the radius of curvature of the horizontal meridian remains the same as at the apex. According to the same formula, $D = 1000 \frac{(n-1)}{r}$, the astigmatism at this point would be 4 D. The difference in the amount of astigmatism at the two points would clearly be 2 D. Of course, this is a much exaggerated case, but it serves to illustrate how a large angle *alpha* may affect the readings of the ophthalmometer, and how the astigmatism at the apex of the cornea may vary from that at the point on the cornea intersected by the visual line. This error holds against the double-movable mires as well as the single-movable mire, but not to the same extent, and for this reason: Besides having the radii of curvature of the two chief meridians differ, which difference represents the amount of astigmatism present, the radius of curvature may be different in one and the same meridian and not necessarily have marked irregular astigmatism, as in low degrees of conical cornea, or even where there is no conical cornea, it being a well-known fact that the farther we go

toward the periphery of the cornea the flatter its surface becomes. This slight change[1] of radius of curvature in the same meridian may be present in one or both of the two chief meridians of curvature. Moreover, the difference in the radius of curvature in the same meridian is likely to be greater the farther away the secondary point of measurement is made from the primary. Herein, in fact, lies the advantage of double-movable mires over the single-movable mire. With double-movable mires, both images remain the same distance from the point on the cornea under measurement, and relatively closer to it than in the single-movable mire. For, as has already been pointed out above, in the instrument with the single-movable mire, one mire must remain fixed at 20° from the center of the arc, while the other may be nearer to or farther away, accordingly as the radius of curvature happens to be longer or shorter than 8.38 mm., the radius of curvature of the cornea (and the only one, by the way), which, by Javal's old instrument, allows the movable mire to be exactly the same distance from the center of the arc (20°) as the fixed mire is, and the images touch. If shorter than 8.38 mm., both images will become smaller, and to a relative extent, if the curve is constant; and the movable mire would have to be displaced farther than 20° on the arc in order to have the images just approximate. If the surface of the cornea, from which this image of this relatively too far displaced movable mire is reflected, happens to have a radius of curvature (in one and the same meridian) slightly shorter than that point on the cornea from which the image of the fixed mire is reflected, then the image from the movable mire would be actually smaller than that from the fixed mire. Again, if the radius of curvature happens to be longer than 8.38 mm., both images will be larger, and the movable mire would have to be moved closer than 20° in order to have the images touch. Consequently, the image from the fixed mire, in this instance, if the surface from which it is reflected is shorter in radius of curvature than that from which the image of the movable mire is reflected, will be actually smaller than that from the movable mire. Conversely to both of the above cited cases, and as most often happens, when the radius

[1] When it is remembered that exactness to the fraction of one one-hundredth of a millimeter in measuring the radius of curvature of the cornea is demanded, the importance of noticing even slight changes of curvature in the same meridian will be apparent.

of curvature of the surface of the cornea, from which the image of the relatively too far displaced mire is reflected, is longer than that from which the image of the relatively too close mire is reflected, the amount of astigmatism, as measured by the single-movable mire, is greater than when measured by the double-movable mires. Furthermore, other things being equal, the farther removed this image of the relatively too far displaced mire is from the center under measurement, the greater the change in the surface of the cornea is likely to be, with, of course, a resultant increase in the error. With double-movable mires, this error does not obtain to the same extent as with the single; hence the advantage of the former over the latter. However, if there was no advantage in this respect, it is a plainly desirable thing to have both mires move and be kept at an equal distance from the center of the arc, and their images equidistant from the center on the cornea under measurement.

In a year's experience with the double-movable mires I have found, in astigmatism of a comparatively small amount — from one to four diopters, with little or no hyperopia or myopia, and the angle *alpha* nil or very small — that the readings differed but little from those of the single-movable mire, the readings with the double-movable mires most of the time being less than with the single-movable mire, about .25 D. to .50 D. less. On the other hand, in astigmatism of large amount, especially when associated with a high degree of hyperopia or myopia, where the angle *alpha* is usually large,[1] the readings have differed more, often as much as .50 D., and sometimes as much as 1 D., the double mires usually giving the less amount. Furthermore, the subjective tests corresponds closer with the readings of the double mires than with those of the single-movable mire.[2]

In irregular astigmatism the readings with the double-movable mires proved much more satisfactory than the readings with the single-movable mire.

The *modus operandi* of the double-movable mires consists in a thumb-screw attached to the arc on the same side as the graduated or movable mire, about two inches from the telescope. On the attached end of this screw are cogs, into which other cogs on slender

[1] The angle *alpha* in these cases was measured with candle and perimeter.

[2] I have used the double-movable mires for five years now, and am more favorably impressed with them than ever.

shafts extend to each mire play (Fig. 105, A). Thus, by a simple turn of the screw, both mires are moved at the same time to an equal extent, in or out, and at pleasure. In this way both mires are kept the same distance from the center of the arc in every case.

Having both mires move at one time necessitates the regraduation of the arc, both for radius of curvature and for diopters.[1] The regraduation for the radius of curvature is obtained by the formula: $O : I :: D : +\frac{R}{2} : \frac{R}{2}$, which reduced is, $R = \frac{2\,D\,I}{O - I}$. In this formula

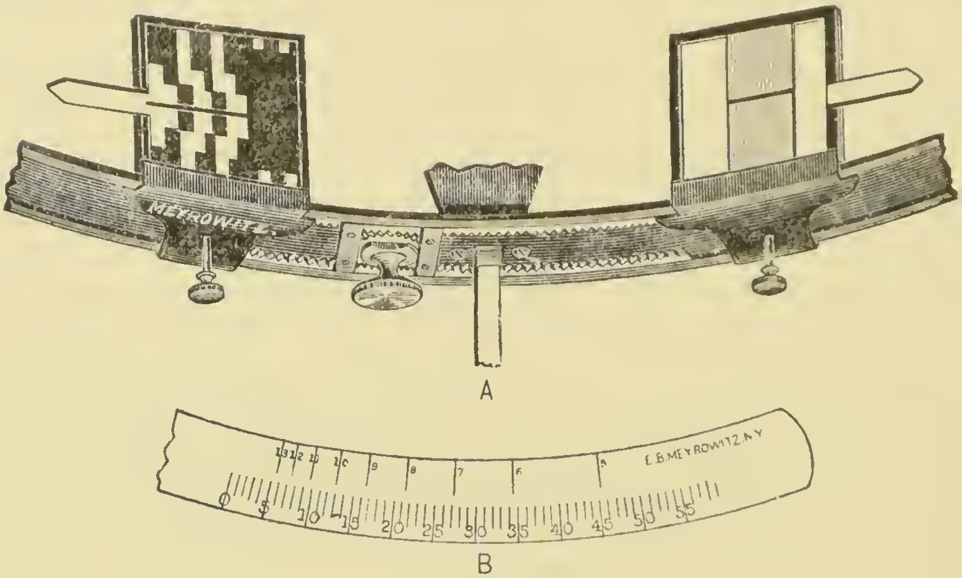


Fig. 105.

R represents the radius of curvature to be found; O, the object, which in Javal's instrument is the imaginary line between the inner edges of the reflectors or mires; I, the size of the corneal image, which is constant, and equals 2.95 mm.; D, the distance of the object O from the cornea, also a constant quantity, 560 mm. being double the focal distance of the objective, which in Javal's instrument is 280 mm.[2]

[1] So far as the diopter marks on the posterior border of the arc are concerned, perhaps it would be as well, or better even, not to regraduate for them, but to leave them as they are. Because, by leaving them as they now are, the number of diopters corresponding to any radius of curvature is easily obtained by simply doubling the number of diopters indicated by the graduated mire.

[2] This is the focal distance given by Dr. Sulzer; also 2.95 mm. is the size of the corneal image given by this writer in his description of Javal's instrument (*Description de l'ophtalmomètre Javal et Schiötz, modèle* 1889, par le Docteur Sulzer, de Winterthur).

To obtain the radius of curvature to be marked in millimeters on the inner edge of the arc, corresponding with the 20 D. mark on the posterior edge of the arc, we have

$$R = \frac{2 \times 280 \times 2.95}{200 - 295} = 8.38 \text{ mm.},$$

and so on, as low down as 6 and as high up as 46, respectively, on each side of the 20 D. mark, the radius of curvature ranging from 13 mm. for the 6 D. mark to 5 mm. for the 46 D. mark (105, B). This doubles the width of range of the instrument with the single-movable mire, and is of service in conical cornea or in very high degrees of astigmatism often present after cataract extraction.

To regraduate the posterior edge of the arc for the new diopter marks it is only necessary to begin at the 20 D. mark as it now stands, and, going each way, divide the diopter spaces into halves, giving to each half the same value that the whole space now represents, and number them accordingly. For example, where 21 now is, 22 should be placed; where 22 is, 24, and so on; and on the other side of the 20 D. mark, where 19 now is, 18 should be written, and where 18 is, 16, and so on (see Fig. 105, B).

Valk's Gear-wheel Attachment

Consists simply of a small cogwheel attached to the side of the telescope back of the large disk, with the cogs in this small wheel

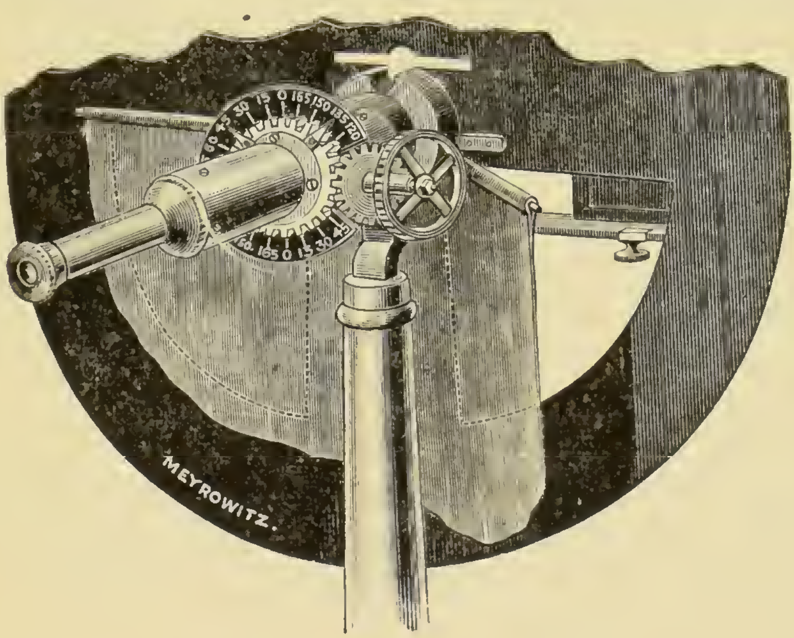


Fig. 106.

made to fit into cogs which have been placed around the telescope (Fig. 106). By this arrangement the telescope can be revolved evenly and the arc and pointers moved for very small distances and maintained at any position given them.

Skeel's Perpendicular Lever Adjustment

By means of a lever placed in the posterior foot of the the tripod, the upright, together with the whole instrument, can be raised or lowered in a perpendicular direction. This is certainly an improvement to the tilting backward and forward movement given to the

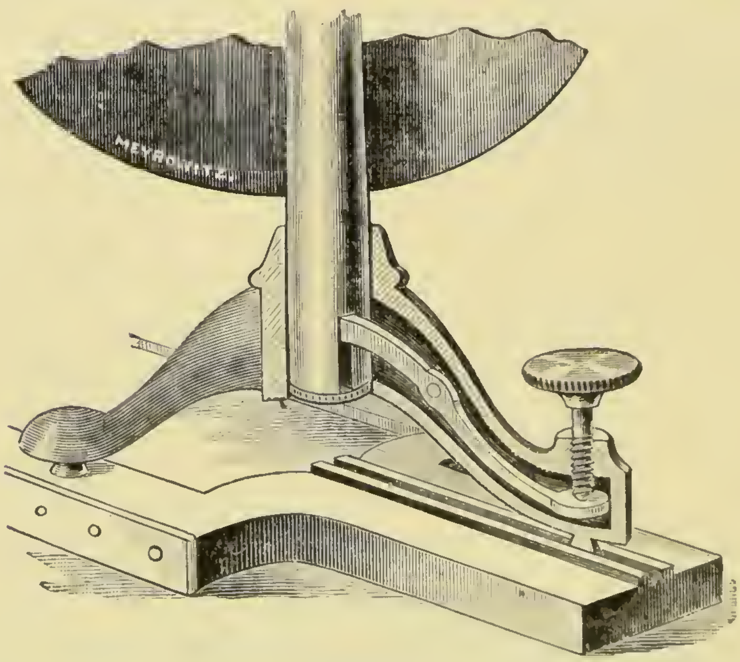


Fig. 107.

instrument when the simple screw alone is used, as in the old instrument (Fig. 107).

Other minor improvements on the chin-rest, forehead-rest, rack and pinion for the mires, shade, curtains to keep light from the eyes of the observer, etc., have been made. The adjustable forehead-rest made by Fox and Stendicke, of this city, is of practical advantage.

Drs. Giles and Chapman have made some modifications in the instrument so as to make it portable, that is, to be carried in a convenient case. See description of same in *Medical Record*, July 25, 1896.

Dr. W. S. Dennett, of New York, has made an improvement on the electric light attachment.[1]

Meyrowitz's solid metal base for the instrument to rest on is much preferable to the old wooden base or planchette of the imported instrument.

Accurate measurements without any of the above improvements, however, can be made with the 1889 model, simply by taking a little more time and care. Those who do not care to go to the expense of adding all of the improvements to an already expensive instrument can procure the unimproved instrument at a moderate cost.

Meyrowitz has made a new model of the Javal-Schiötz ophthalmometer. In this model he has left off the large dial of Placido, and replaced it with a smaller black dial. At the same time he has added a smaller dial at the back of the telescope, by which the axis of the astigmatism is read off.

The advantages claimed for this model are: (1) That the tripod supporting the instrument is permanently attached to the base, thereby giving it greater steadiness, and is moved forward and backward by a rack and pinion, while the lateral motion is given by a revolving joint at the foot of the tripod; (2) The improvements made on the 1889 model of the Javal instrument are retained. Among these are the "perpendicular adjustment" of the entire instrument (Skeel's), and the "simultaneous movement" or "double-movable mires" (Davis's). A new and important improvement to this latter movement has been made by the addition of a beveled gear attachment which permits the manipulation of the mires from the back of the large dial; and by means of a circular scale with double automatic pointers corresponding to the graduations on the arc, the relative position of the mircs on the arc can be read with great accuracy.

Another new feature is the raising and lowering of the chin-rest from the opposite end of the ophthalmometer, by means of a cam operated by a long rod and milled head at the end of same, so that the operator need not change his position. Below a good cut of the instrument is given.

Another new model of the ophthalmometer is that made by Chambers and Inkeep, of Chicago. The special advantages that

[1] *New York Eye and Ear Infirmary Reports*, 1894, II. 27.

they claim are: (1) Stationary luminous mires; (2) Adjustable prisms.

There are still other models of the instrument on the market, but, in my opinion, the 1889 model of Javal and Schiötz is as accurate as any of them. Not only that, but measurements outside of

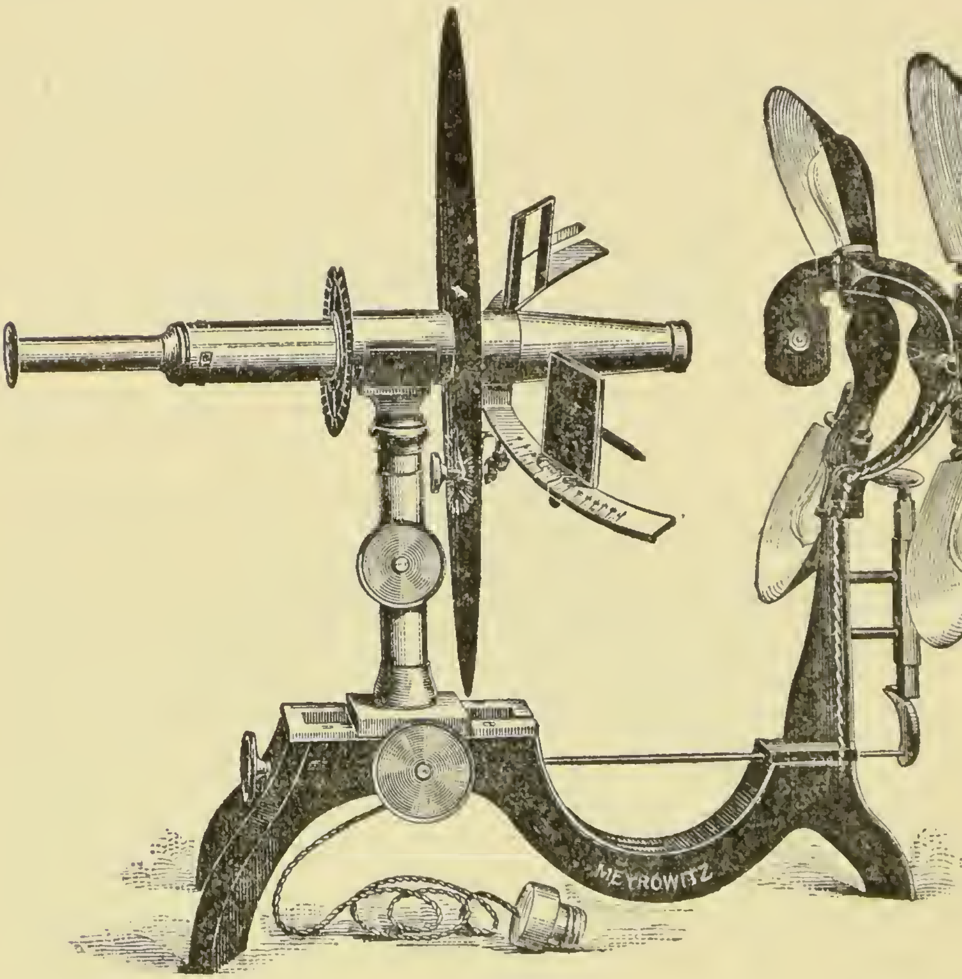


Fig. 108.

the visual line can be made with the 1889 model, because it has the large dial of Placido attached, while all of the new model instruments have replaced it with a plane black disk or dial.

Artificial Corneæ

Some eight or nine years since, Javal made an artificial cornea, astigmatic in nature, which could be attached to the chin-rest of the instrument, and used for testing the correctness of the ophthal-

mometer itself. Since the radii of curvature of the principal meridians of this artificial cornea are known, and their exact refractive power in the equivalent diopters, it is easy to tell if an instrument is at fault in its measurements. The meridian of shortest radius of curvature represents a refractive power of 44.2 D., while the meridian of longest radius represents a refractive power of 42.5 D. The difference between these two numbers gives the amount of astigmatism of the artificial cornea, 1.7 D., which of course is constant. The axis of this astigmatism, however, can be changed at will, since the cornea is on a movable disk. The meridian of shortest radius of curvature is indicated by an arrow. Consequently when the arrow points to 0° (directly above on the rim), the astigmatism is with the rule; and when pointed horizontally to 90°, the astigmatism is against the rule. All intermediate positions, of course, can be taken. Because of the brilliant images which it gives, and the fact that it can be looked at for a long while, make it of much practical value to the beginner, because he can practice on it.

FIG. 109. — Javal's Artificial Cornea.

Morgan's artificial cornea has been constructed to be used in connection with the Javal ophthalmometer. It consists of a highly polished glass hemisphere, ground to the radius of a normal cornea, and placed in the center of a graduated cell, similar to such as are found on trial frames. When attached to the head-piece of the ophthalmometer, the cornea occupies the position intended for the eye of the patient. In this way the ophthalmometer can readily be tested, and adjusted if necessary. For purposes of demonstration, this normal cornea can, by the insertion of a cylindrical lens

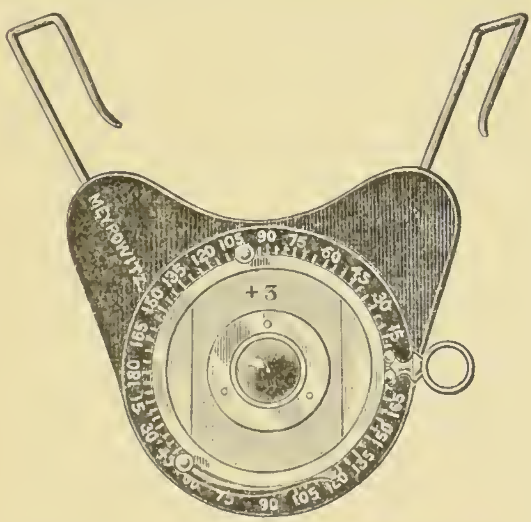


FIG. 110. — Morgan's Artificial Cornea.

into the revolving cell, be converted into an astigmatic cornea of any desired degree, with the axis at any given angle.

Reid's Ophthalmometer

The inventor's original description of his instrument is as follows:[1] "The object of the instrument about to be described is to measure the curvature of the central area of the cornea, the polar or optical zone; or of any spherical reflecting surface from 6 to 10 mm. radius. In its present form the instrument can only be applied to the measurement of the corneal surface in the visual line. As this is the area of the cornea utilized for distinct vision, this instrument furnishes all the data practically requisite for the diagnosis and measurement of corneal astigmatism.

"The theory of its construction is based on a particular application of the following well-known optical law: That when two centered optical systems are so combined that their principal foci coincide, the ratio of the size of the object to the size of the image formed by the combined systems is equal to the ratio of the principal foci of the two optical systems, adjacent respectively to object and image. The two optical systems in this case are the convex lens of the instrument and the cornea as a reflecting surface, with the object in the principal focus of the adjoining optical system.

"Thus (*vide* Fig. 1): —

"Let MM' be the convex lens of known surface, A the corneal surface, and P' the point where the principal foci coincide.

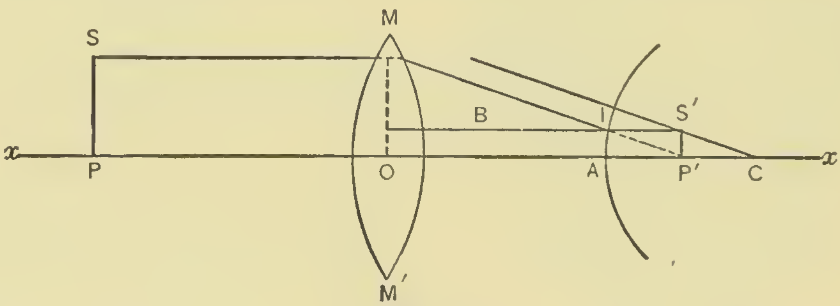


Fig. 1.

"Let SP be an object situated at the principal focal distance of MM', and let XX' be the principal axis of the system.

"Then a ray SM parallel to the axis will, after refraction, be

[1] From the *Annals of Ophthalmology and Otology*, April, 1896.

directed to the principal focus P' of the curved surface of the cornea, and therefore be reflected in the direction IB parallel to the axis XX'. IB prolonged will meet the ray directed to the center C at the point S'; therefore, S' is the image of S, and $S'P'$ is the image of SP, and $S'P'$ is in the principal focus of the convex reflecting surface.

"In the similar triangles $MP'O$ and $IP'A$,

$$\frac{P'O}{P'A}=\frac{MO}{IA'}.$$

SM and IS', the prolongation of the reflected ray, are parallel to the axis XX', therefore $SP = MO$ and $S'P' = IA$.

Therefore $$\frac{P'O}{P'A}=\frac{SP}{S'P'}, \quad \text{or} \quad \frac{O}{I}=\frac{F}{f}$$

$$f=\frac{r}{2};$$

therefore $$\frac{O}{I}=\frac{2F}{r}. \quad \ldots \ldots \quad (1)$$

$$r=\frac{2F\times I}{O}.$$

"*Description of the Instrument*

"The essential parts of the instrument are an aplanatic convex lens of known focus, a rectangular prism neutralized in its center by a smaller prism, one side of the rectangular prism being adjacent to the lens, and a circular or other disk being opposite the other side in the principal focus of the lens. When the instrument is held in front of the convex reflecting surface with the disk turned toward a luminous source, a virtual image of the disk will be formed at the virtual focus of the convex reflecting surface. This image will only be seen distinctly by the emmetropic eye through the neutralized portion of the prism when the focus of the lens in front coincides with the virtual focus of the convex surface. The ratio of the object to the image will be as shown above. If now a double-image prism be inserted behind the neutralizing prism, which exactly doubles this image, its power with the combination is easily determined, and therefore the exact size of the image can be measured.

The size of the object being known, we have the three elements necessary for determining the fourth proportional, the curvature of the convex reflecting surface.

"The instrument in this simple form presented a number of practical difficulties in its manipulation, which were overcome by the introduction of a short telescope behind, with double-image prism fixed in front of its object-glass.

"In its present form the instrument consists of the following parts (*vide* Fig. 2[3]): An aplanatic lens *Ob*, a rectangular prism *P* neutralized in the visual axis by a smaller prism P^2, and a telescope, with the double-image prism *BP* fixed in front of the object-glass of the telescope OB^2. The focal length of the object-glass OB^2 is precisely the same as that of the aplanatic lens *Ob*, and cross-wires *CW* at its principal focus are viewed by a Ramsden eye-piece.

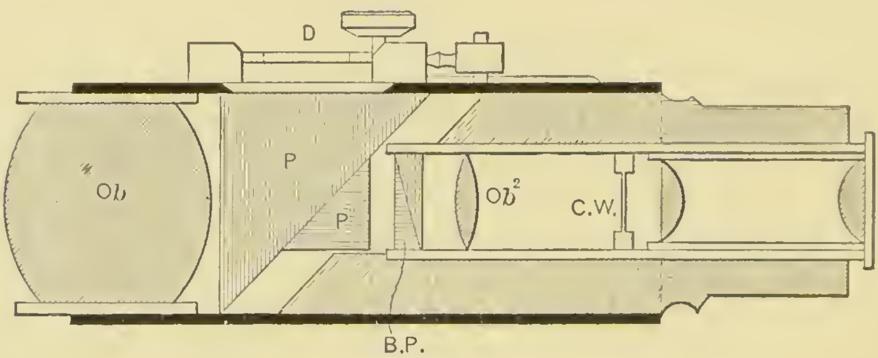


FIG. 2.

"Before using the instrument it is necessary and sufficient that the cross-wires should be distinctly seen at the punctum remotum of the observer. The adjusted instrument is held in the observer's left hand, which rests on the forehead of the patient, the disk being directed to a luminous source to the right of the observer. The point of coincidence of the principal foci is found by moving the instrument to and fro. When the observed eye is directed to the central or fixation point and his visual line is vertical to the point of the cornea through which it passes, the corneal image doubled and inverted ought to be seen in the center of the field. Instead of using circular disks of different dimensions, the size of the image required to produce exact contact in any meridian is conveniently and quickly obtained by making the required change in the size of a carefully constructed iris diaphragm. By using a circular object the circular,

elliptical, or irregular form of the image reveals at once the condition of the surface. When the image is elliptical the meridian of greatest curvature is easily found by rotation of the telescope, and a rotation of 180° gives a controlling observation. By a similar process the meridian of least curvature is determined.

"*Graduation of the Instrument*

"Let D be the power in diopters of the cornea as a refracting surface, with a medium behind it of uniform density having an index of refraction $n = 1.337$ approximately.

$$D = \frac{(n-1)1000}{r}$$

$$= \frac{337}{r} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (11)$$

"Combining equation (1) with (11),

$$D = \frac{337 \times O}{2\,IF}$$

$$D + 1 = \frac{337 \times O'}{2\,IF}$$

$$1 = \frac{337}{2\,IF}(O' - O).$$

"In the present instrument $I = 2$, and $2\,F = 52$,

therefore $$I = 3.24\ (O' - O),$$

$$\frac{I}{3.24} = O' - O;$$

therefore $ID =$ rather less than $\frac{1}{3}$ mm.

"The index is divided into two parts, outer and inner. The outer registers the size of the image, and the inner the corresponding diopters.

"The degree of refinement with which the measurements may be carried out depends entirely on the degree of exactness of determination of the constants, especially I and F. I has been determined exactly to $\frac{1}{500}$ inch, and can be estimated to about $\frac{1}{1000}$. The focal length of the object-glass can be determined by Cornu's method, but in general it is more convenient to measure two-curved

surfaces whose radii are exactly known, and within the limits of the instrument.

"The index error is found by taking the number of diopters at sufficiently great intervals within the limits of the instrument. In this instrument, if we take the extremes of the index, 0 = 12 mm. and 0 = 16 mm., we find the corresponding diopters are 38.9 D. and 51.84 D. The index being graduated in thirds of a millimeter, the index error of each division is nearly 0.08 D., which is positive.

"If the double prism be now removed, the image being single, and the pupillary opening generally distinctly visible, it affords a means of determining whether the visual axis passes through the center of the pupil.

"It will be seen that this instrument differs from the ophthalmometer of Helmholtz, the most perfect instrument theoretically and practically which has been devised for this purpose, in which, while the object is constant, the image varies with the curvature of the surface, but always covers the same angular interval of the surface. It resembles the *ophthalmomètre pratique* of Javal and Schiötz, in which the doubling is effected by means of a double-image prism inserted between two achromatic lenses of equal focus, so that while the image is constant the object is made to vary. With this instrument, when the difference of curvature of the principal meridians is considerable, amounting to 3 or 4 D., in order to obtain approximately accurate results, it is necessary to insert bi-refractive prisms of different powers, giving images of from 1 to 3 mm. In the present instrument the image of 2 mm. has been selected as giving sufficiently accurate results for the most practical purposes, measuring with precision, as it does, a difference of refraction of half a diopter. For cases outside the limits referred to (6 to 10 mm.) prisms of suitable powers can be substituted."

Through the courtesy of Messrs. J. H. & G. W. Hahn, New York City, I had the use of a Reid's ophthalmometer in my office for about five months' time, and I wish to express my thanks in this place to the Messrs. Hahn for their kindness in the matter.

In that time I had many opportunities to compare it with the Javal-Schiötz instrument in testing for astigmatism.

In astigmatism of low and moderate amount, up to 4 D., I found it as accurate as the Javal-Schiötz ophthalmometer, as to *amount*. I must say, however, that it was not so accurate in placing the axis

of the astigmatism. Especially was this so in astigmatism against the rule. Dr. Murdock, of Baltimore, who is familiar with the instrument, praises the instrument highly, in fact, believes it more accurate than the Javal-Schiötz instrument, though he found the same difficulty in finding the exact axis in astigmatism against the rule that I have spoken of. He says: "Its weak point, in my hands, but not in Dr. Reid's, is the difficulty encountered in determining the exact angle of an axis against the rule. The two images that one looks at are circles, and I find it difficult to tell when they first separate or when they reach the furthest point of separation."[1]

In high amounts of astigmatism, as in conical cornea and after cataract extraction, it was not equal to the Javal-Schiötz instrument by any means; in fact, in the very high amounts of astigmatism, it could not measure it even approximately.

In comparison with the Javal-Schiötz instrument it suffers under the further disadvantage of not giving the radius of curvature of the cornea in millimeters, as does the former instrument. It is true that the radius can be calculated by a simple formula, but in office work we do not care to waste time in such calculations. There is no question but that it is a handy instrument as a *portable* ophthalmometer, and is easy to use; but, as a rule, patients who want glasses fitted are able to come to the office of the oculist. Besides, in America at least, we have a portable Javal-Schiötz ophthalmometer (Drs. Giles and Chapman's). In conclusion, I may say, the cost of the two instruments is about the same.

Dr. C. A. Oliver, of Philadelphia, has invented an adjustable bracket for the Reid ophthalmometer,[2] his description of which is here appended: —

"After several years' trial with the various forms of ophthalmometers (keratometers) and much experimentation with the Reid contrivance (by far the best of them all), I have found that for office use I have been able to obtain much better results as regards both axis and degree of corneal astigmatism by having the instrument mounted upon an adjustable table, which, by the employment of four leveling screws and a circular form of spirit-level, can be kept absolutely level in all horizontal directions during the examination,

[1] *Annals of Ophthalmology and Otology*, April, 1896, p. 324.

[2] Read before the December, 1898, meeting of the Section on Ophthalmology of the College of Physicians of Philadelphia.

thus insuring a greater degree of certainty of answer in reference to axis than when the instrument was held in the hand.

"The apparatus practically consists of a rigid, vertical, steel rod holding a sliding bracket, upon which there is fixed a combined leveling table containing the instrument.

"The ophthalmometer itself is held in position by two angular supports that are bolted to the upper table, and is so arranged that a mere pressure by the hand will release it from their grasp, thus making it portable and allowing it to be used as originally intended.

"Rising from the circumference of the table there are two fixed rods, holding on their upper tips a pair of horizontally placed sleeves, through which can be slid a fixation bar that can be bolted into any position that may be desired by a few turns of two screw-heads that pass through threaded openings in the upper parts of the sleeves. The rod that is placed on the registering side of the instrument contains a large circular area, which is situated just opposite to the position of the translucent dial.

"Situated on the top of the table is a carefully constructed, broad, circular level composed of a metallic air-tight chamber, covered by glass. In the center of the glass cover is an etched circle of one centimeter diameter. This chamber, with the exception of an area which is of the same size as that of the etched circle on the glass cover, is filled with alcohol, — thus making a bubble of air which, if the table be level in every horizontal direction, will be situated immediately beneath, and rendered exactly coincident with the etched glass area above. At the periphery of the table, between the circular spirit-level and the edge of the table, there are four fenestrated, threaded heads passing through the entire thickness of the table itself.

"Beneath the upper tilting or instrument and spirit-level holding table there is a leveling or fixed table fastened firmly to an upright supporting rod. Upon this table four immobile pointed heads are situated.

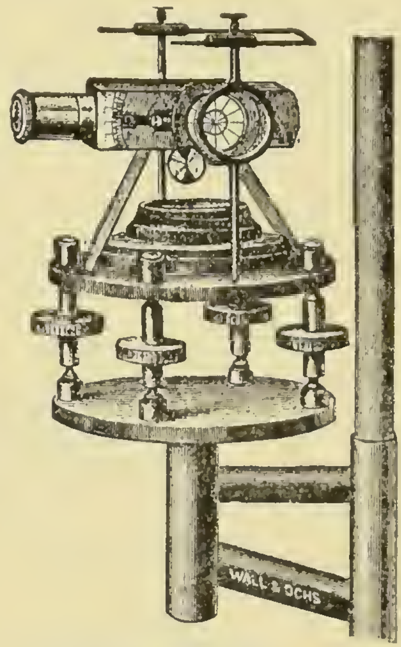
"Between the two tables, loosely supported on the four pointed cones of the lower table, there are four grooved, broadly headed leveling screws that pass through the fenestrations in the upper table, so that the slightest turn given to any one of them will cause the bubble of air in the spirit-level to change its position.

"In the latest model of instrumentation (not shown in the sketch)

there is a central spiral spring firmly held in an upright position between the two tables, by which means the upper table is kept securely fixed in whatever position the leveling screws may have placed it.

"To the ophthalmometer itself there has been added (which cannot be seen in the sketch) a scale by which the exact axis of the meridia of the greatest and the least corneal refraction can be immediately read off.

"If desired, the instrument and the leveling tables may be supported on an optometer or phorometer bracket or tripod, or they can be screwed to the top of a table or clamped to the back of a chair, thus making them very light and easily transportable.



Adjustable bracket for the Reid ophthalmometer.

"To use the instrument, the vertical rod is bolted to a window-frame in such a way that by a mere turn of the bracket either eye may be studied (or if so desired the window curtain can be drawn and either a source of artificial illumination substituted for the daylight, or, as the author prefers, a small adjustable aperture in the opaque shade may be opened and the diffuse daylight allowed to fall directly upon the disk).

"The patient being placed in position, and the ophthalmometer properly adjusted, the work is proceeded with in the ordinary way."[1]

Hardy's Ophthalmometer[2]

"The first ophthalmometer was designed by Helmholtz, in the first half of the present century; but the principle involved therein was not reduced to practical utility until 1884, when Doctors Javal and Schiötz, in Paris, designed the present model. The principle on which it is based is *the measurement of corneal curves by means of reflected images* viewed through a telescope.

[1] *University Medical Magazine*, July, 1899.

[2] Description taken from Hardy's catalogue.

"Images reflected from curved surfaces will vary in size according to the radius of curvature of those surfaces, when the objects reflected therefrom are uniform in size and distance. For instance, a circle 20 cm. in diameter, placed at 28 cm. distance, would produce a larger reflected image on a cornea which has a long radius of curvature than would be produced on one with a

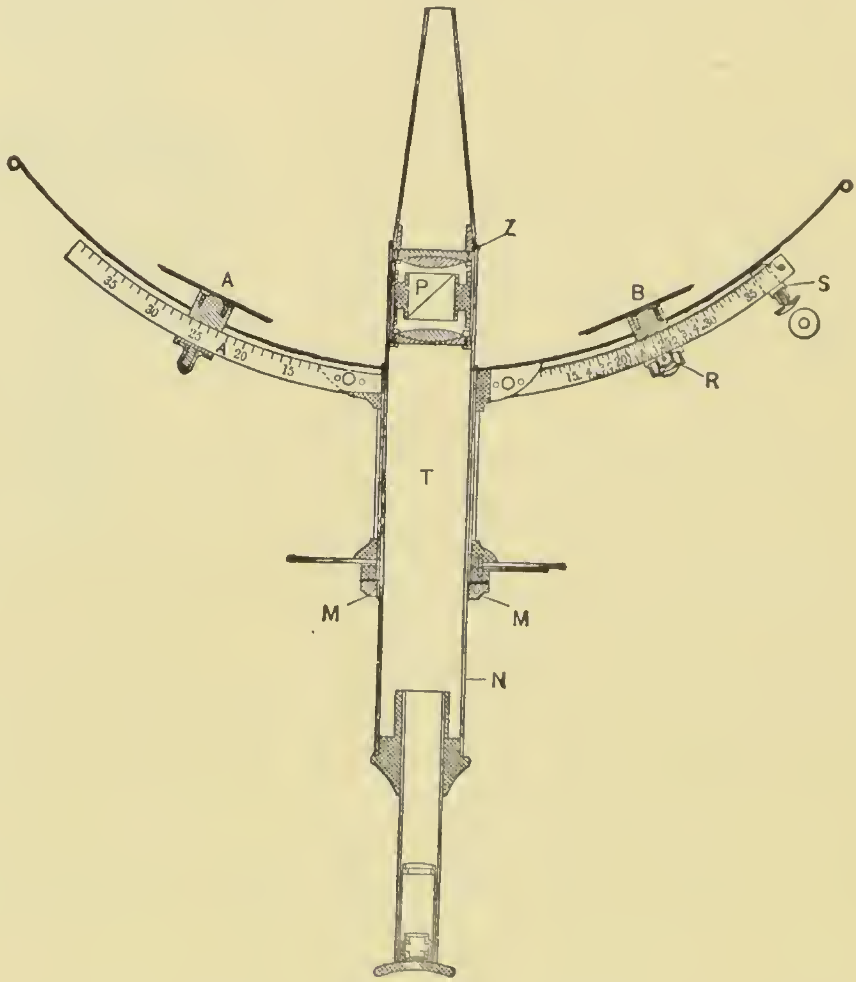


FIG. I.

shorter radius. So that, if it were possible to measure the size of the images of the above object reflected from a cornea, the exact radius of curvature of that cornea could be calculated. Or, conversely, if an image of a given size, say 3 mm., is reflected from the cornea, the curvature of the latter can be calculated from the size of the object required to produce 3 mm. at 28 cm. distance. It is evident, therefore, that the problem to be solved in constructing an

ophthalmometer has been how to either measure the size of the image reflected from the cornea, or to obtain on the cornea an image of a fixed size, say 3 mm. in diameter.

"The device employed accomplished both of these results, and is shown in section in Fig. I.

"It consists of a telescope 'T,' to which are attached arcs carrying sliding targets 'A' and 'B,' called 'mires.' The telescope has a combination of lenses such that a surface, when viewed through it, will be exactly in focus when the mires 'A' and 'B' are at 28 cm. distance therefrom. By this means the first element is obtained, namely, a fixed distance between the cornea and the object to be reflected from it.

"Between the two objectives of the telescope there is placed a bi-refringent prism 'P.' This is a prism which has the property of doubling in one plane objects seen through it. For instance, a circle viewed through the telescope containing the prism will appear doubled. The prism is so adjusted that when the telescope is in focus the distance between any two corresponding points of the doubled images will be exactly 3 mm.; consequently, when a cornea is viewed through this instrument, it is seen doubled, the reflection of the mires from the cornea also being doubled, and the distance between either edge of the two images of one of the mires would be exactly 3 mm. In Fig. II is shown an enlarged view of the cornea, with the mires reflected on it, as seen through the telescope.

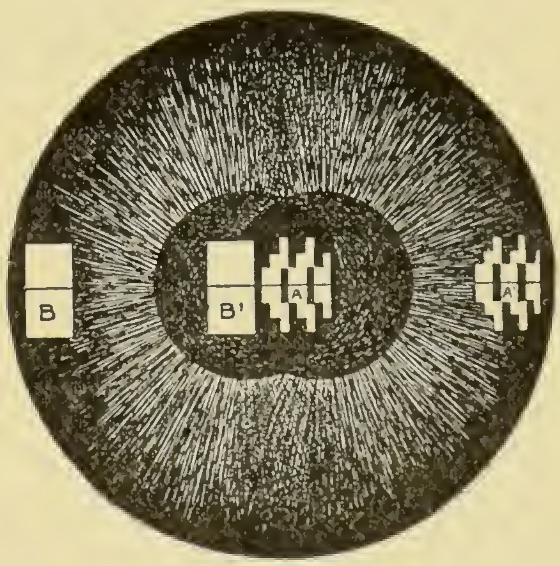


Fig. II.

"Now, if the distance between the right-hand edge of the primary image of the stepped mire 'A,' and the right-hand edge of its secondary image 'A',' is exactly 3 mm., and if the right-hand edge of the secondary image 'A'' is exactly in contact with the left-hand edge of the primary image 'B,' of the other mire, it is at

once evident that the distance between the inner edges of the two mires on the arcs is equal to the size of the object which will give on the cornea a reflected image 3 mm. in diameter. Consequently, we have here all the means of calculation needed to give us the radius of curvature of the corneal surface.

"The mires are made movable on the arcs, one of them having a rack and pinion ('R,' Fig. I) for fine adjustment, so that the operator, while looking through the telescope, can slide the mires away from or toward each other, until their two central images on the cornea appear in contact. The arcs are graduated on their inner edges by a scale giving the refractive power in diopters and quarters of a plano lens having the same curve as the corneal curve indicated by the position of the mires. A scale is also provided on the other edge of the arc, giving the radius of the cornea. But, as the instrument is chiefly used for diagnosing astigmatism, the first scale is the important one.

"The mires are formed as shown in Fig. III: one has a simple white block; the other, with a series of steps, arranged in groups, so they can be readily counted; both having a black line bisecting them, and a black background.

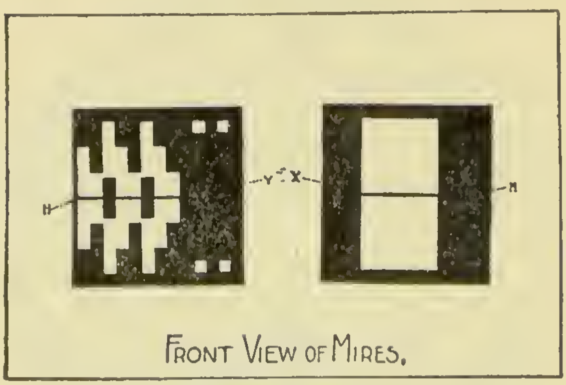


FIG. III.

"On the stepped mire, each step represents a diopter, the distance between the edge of the first step and the line of the edges of the small white squares represents a diopter, and each of the small squares and the black space between them represent diopters.

"The arcs carrying the mires being farther away from the cornea than the mires themselves, in other words, being on a circle of longer radius than that in which the mires move, the difference in the radius is allowed for in the graduation of the arc.

"The mathematical principle governing the construction of the instrument is, that a given distance between the mires and the cornea of 28 cm., and a separation of the images by the bi-refringent prism of 3 mm., then each 5 mm. of distance between the inner edges of the two mires is equal to 1 D. in a medium having the

refractive power of a human cornea. So that the size of the steps of the mire must be exactly 5 mm., and the graduation on the arc enough farther apart to compensate for its longer radius.

"The numberings of the graduations on the inner edge of the arc, therefore, are intended to show the number of half-centimeters' distance between the inner edges ('X' and 'Y,' Fig. III) of the white spaces on the two mires. The two edges above mentioned are set on the slide carrying them, so that they are exactly in line with the inner edges of the slides. And the graduation on the arcs next to the inner edges of the slides, added together, give the readings of the instrument. For instance, in Fig. I the inner edge of the mire 'A' stands at about $22\frac{1}{2}$ on the arc, that of the mire 'B' at $22\frac{1}{2}$ on its arc, making about 45 D. together; and if the corneal reflections of the mires placed on the arcs as above have their inner edges *just 'in contact,'* as shown in Fig. V (not separated or overlapping, as shown in Figs. VI and VII respectively), then the cur-

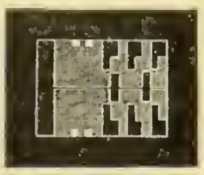


Fig. V.

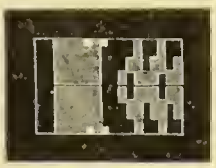


Fig. VI.


Fig. VII.

vature of the corneal surface indicated by the positions of the slides on the arcs in that case would be such as to produce a focus of 45 D.

"There is no such thing as a normal curvature for the human cornea, but from statistics a radius of curvature of 7.829 mm. has been settled upon as that of the average cornea. Accordingly, we have stamped on the arcs the letter 'A,' to indicate the position of the mires for a cornea of average curvature. A smaller distance *between the slides* than that shows a corneal curve of less than the average, and, hence, a *presumption* of hypermetropia. A greater distance indicated the reverse of the above, or a *presumption* of myopia.

"The images of the two mires reflected from the cornea being farther apart on a cornea of longer curvature, or nearer together on one of shorter curvature, it follows that, by moving the mires until their images appear in contact (Fig. V), the curve of the cornea can be read off on the arc, as stated above, and the difference

between the curvatures of the same cornea in different meridians can be determined in the same way.

"But the main object of the instrument is not to show the absolute curvature of the cornea, but differences of curvature in its different meridians, *i.e.* astigmatism. Hence, the stepped mire is provided, which indicates the amount of astigmatism existing by the overlapping or separation of the mires when rotated to the opposite meridian from that in which they were brought in contact.

"The angles of the two principal meridians are determined as follows: The action of the bi-refringent prism is only in one direction, and the line or plane of its action is exactly in the plane of the arc carrying the mires. By placing on the mires a black line ('H,' Fig. III) also exactly in the plane with the arcs and the action of the prism, that line will only appear continuous through both images when it is reflected from one of the principal meridians. When reflected from any other meridian, the mires will appear as in Fig. VIII, with the black line broken.

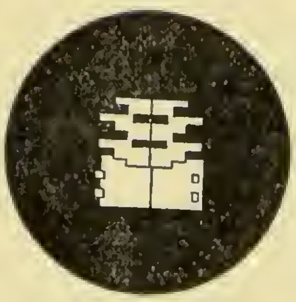


Fig. VIII.

"The telescope is mounted on a tripod, as shown in the cuts, and rests upon the stand containing the chin-rest for the patient. It is rotatable, allowing the arcs to be set at any meridian, their position, and also the meridian at right angles to it, being shown by the index fingers on the graduated disk.

"The whole instrument can be slid back and forth on the stand, so as to focus it on the patient's cornea.

"The telescope, being provided with the correct combination of lenses for that purpose, will show a clear image to an observer having normal vision, when the mires are exactly 28 cm. distant from the cornea.

"Any error in the eye of the observer will affect the distance by *about* $\frac{1}{2}$ mm. to each diopter of such error. That is to say, if the oculist using the instrument is myopic 2 D., it would focus with the mires at 281 mm. from the patient's cornea, in place of 280 mm. Hence, the readings of the instrument would be vitiated to an amount of about $\frac{1}{500}$ of a diopter for each diopter of error in the eye of the oculist.

"Doctors Javal and Schiötz corrected this by providing cross-

hairs in the tube holding the eye-pieces, so that by focussing it upon them the error in the oculist's eye could be compensated. But this error is so slight, and it is so utterly impossible to construct an instrument in which it would have any practical effect, that we regard the cross-hairs as an unnecessary obstruction to the view, and therefore omit them.

"In practical use, the main and most important feature of the instrument is its definition. For the object viewed through it is an image so small that each step on the stepped mire is less than $\frac{1}{10}$ of a mm. in diameter reflected from a surface that is often very dull. So that the lenses must be of very high grade, and their mounting very perfect, to prevent a lack of coincidence in their centering, in addition to which the metal work must be rigid and closely fitted.

"The greatest difficulty met with in the manufacture of ophthalmometers has been that of obtaining perfectly clear quality of quartz for the bi-refringent prisms. All the Paris-made instruments have this style, of prism, with the result that many of them have very poor definition. We have, therefore, lately adopted the glass beveled slabs, as used in the Utrecht make, with the result of a very much better definition than elsewhere obtained.

"*Directions for Use*

"From the above description of the construction of the instrument, the following rules for its use will be easily understood: —

"Place the patient with chin on the rest, and forehead pressed *firmly* against the top of the head-rest, so as to keep the head perfectly steady. Cover one eye with the eye-cover, and tell the patient to look into the end of the tube.

"Set the two targets at 'A,' on the graduated arcs, and revolve the instrument until the arcs are horizontal, and the index fingers pointing exactly to 90° and 180° respectively. Sight through the slot in the large disk, and slide the instrument on the stand until the patient's eye is seen through the center of the slot, and is in line with the telescope, the top of the cone being brought into line with the bottom of the cornea by turning the pinion in the base. (A little practice with the individual instrument will enable its owner to sight very accurately, so that on looking through the telescope the images will be clearly in view.) Then slide the instru-

ment till the reflections of the images are sharply focussed. They will appear double, as is shown in Fig. VIII. The two outer images, 'B' and 'A',' should be altogether disregarded, and the attention fixed solely on the two central images, 'B'' and 'A.' The instrument should be moved till the central images are exactly in the middle of the field of view, as shown in Fig. III, and only now tell the patient to open the eye as much as possible, not only in order to get a better image, but also to prevent pressure of the lids on the globe, which causes often a very considerable degree of astigmatism.

"The next step is to find the principal meridians, which is done by revolving the instrument and noting separation of the two images. The meridian at which the two images appear nearest together is the meridian of greatest refraction, and the meridian at which they appear to be farthest separated is the one of the least refraction. The *exact* meridian is determined by finding the point at which the horizontal line which bisects the two images is exactly continuous, as is shown in Fig. V, instead of broken, as is shown in Fig. VIII. Having found one of the meridians exactly, move the target along the arc by the rack and pinion till the edges of the images are just in contact; then rotate the instrument 90°, and the amount of astigmatism can be determined by the amount of separation or overlapping of the images, as is shown in Figs. VI and VII. The targets in Fig. VII overlap two steps, showing 2 D. of astigmatism. Those in Fig. VI show a separation equal to two steps, as indicated by the square blocks in the margin of the targets, so that in this figure an astigmatism of 2 D. is also represented.

"Concise Rules

"When measuring the amount of astigmatism by the overlapping of the images: —

"1. Focus and find center.

"2. Find meridian of least refraction, viz., that on which the images appear farthest apart.

"3. Approximate the images and find exact axis of the meridian.

"4. Rotate 90°.

"5. Read off amount of astigmatism by overlapping of the images.

"6. Having proceeded according to this rule, the perforated index finger will indicate the axis of the greatest curvature, or that for a plus cylinder, and the solid index finger 'A' will indicate the axis of least curvature, or that for a minus cylinder. (See Fig. XI.)

"The above is the method used with the French instrument, but we have added a new method for determining the amount of astigmatism.

"We have attached to one of the racks a supplementary slide ('S,' Fig. 1) with a set-screw. This slide is on the arc, outside of the slide carrying the target. After having found the meridian of greatest refraction, according to the above method, this supplementary slide should be brought against the slide carrying the target, and should be fixed in position by the set-screw. This can easily be done without moving the eye from the telescope. Then rotate the instrument 90°, when the image will appear to separate, and move the target by the rack and pinion till the edges of the two images again appear to exactly touch. Then note the angles of the two principal meridians, as indicated by the index pointers, and the amount of astigmatism can be read off from the graduations on the arc. These graduations are made by one-quarter diopters.

"The supplementary slide being fastened in the first position, and the slide carrying the target moved away from it to the second position, the number of graduations exposed between the two slides represent the number of diopters and quarter diopters of astigmatism.

"*Distance Concise Rules*

"When using supplementary slide: —

"1. Focus and find center.

"2. Find the meridian of greatest refraction, which is that on which the images appear nearest together.

"3. Approximate the images and find exact axis.

"4. Bring 'indicating slide' against that carrying the target, and fasten in position by the set-screw.

"5. Rotate 90°.

"6. Approximate the images again.

"7. Read off amount of astigmatism on graduated arc.

"8. Having proceeded according to the above rule, the solid index finger 'A' (Fig. XI) will indicate axis of greatest curvature, or that

for plus cylinder, and perforated finger 'B' will indicate axis of least curvature, or that for minus cylinder."

My personal experience with the Hardy instrument extended over a period of about two months in my clinic at the Post-Graduate School of Medicine. I found it a practical instrument and one of precision. In construction it is very similar to Javal's in its main features, and any one familiar with the use of the Javal-Schiötz instrument can use the Hardy instrument.

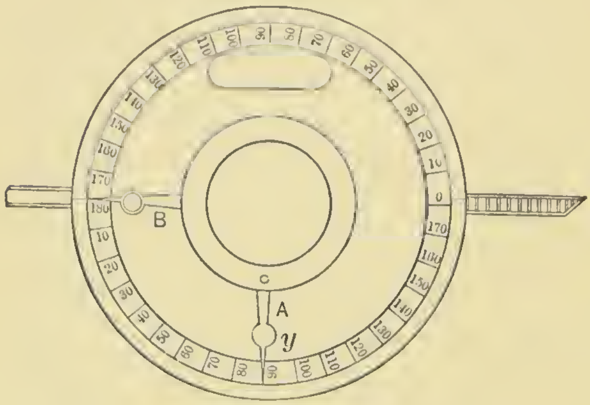


FIG. XI.

With other ophthalmometers, Kagenaar, etc., I have not had personal experience. Dr. George J. Bull's opinion of the Kagenaar instrument, whose judgment in such matters is of much value, is not very favorable, if we are to take his estimate of it as given in a recent article in the *Ophthalmic Record*, Vol. 7, p. 604, on "The Utility of the Ophthalmometer." He says: "Some have supposed that the rival ophthalmometer of Kagenaar or that of Hardy might be looked to with better results. Both ideas are entirely erroneous. The ophthalmometer of Kagenaar (and that of Hardy), although an instrument of considerable merit, has no real advantage as compared with the instrument of Javal, and it has the disadvantage that the amount of doubling produced by its prism varies with the distance of the patient."

All things considered, I myself prefer the Javal-Schiötz instrument to any other, and use it exclusively, except when making comparative tests.

INDEX OF CASES

CHAPTER III

Simple Hypermetropic Astigmatism — Simple Hypermetropia

CHAPTER IV

Compound Hypermetropic Astigmatism — Spasm of Accommodation

CHAPTER VI

Compound Myopic Astigmatism — Antimetropia

CHAPTER VII

Mixed Astigmatism

CHAPTER VIII

Irregular Astigmatism — Conical Cornea

CHAPTER IX

STRABISMUS — INSUFFICIENCIES OF THE RECTI MUSCLES

CHAPTER X

Astigmatism after Cataract Extraction

CHAPTER XI

Exceptional Cases

(1) *Cases showing discrepancies as to the amount of the astigmatism*

(2) *Cases showing variation as to the axes of the corneal astigmatism and total astigmatism*

(3) *Cases with discrepancies both as to the axis and the amount of the astigmatism*

GENERAL INDEX

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P

R

S

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HANDBOOK OF OPTICS

FOR

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BY

WILLIAM NORWOOD SUTER, B.A., M.D.

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CONTENTS

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